NR-864

258

GENETIC, PHENOTYPIC AND ECONOMIC PARAMETERS FOR CONSTRUCTION OF SWINE SELECTION INDICES: CASES OF NEPAL AND THE PHILIPPINES

DRONA P. RASALI

JUNE 1991

MARC IC 1476 B1 P

GENETIC, PHENOTYPIC AND ECONOMIC PARAMETERS FOR CONSTRUCTION OF SWINE SELECTION INDICES: CASES OF NEPAL AND THE PHILIPPINES

DRONA P. RASALI

SUBMITTED TO THE FACULTY OF THE GRADUATE SCHOOL
UNIVERSITY OF THE PHILIPPINES AT LOS BAÑOS
IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE
DEGREE OF

MASTER OF SCIENCE
(Animal Science)

June, 1991

The thesis attached hereto entitled "GENETIC, PHENOTYPIC AND ECONOMIC PARAMETERS FOR CONSTRUCTION OF SWINE SELECTION INDICES: CASES OF NEPAL AND THE PHILIPPINES", prepared and submitted by DRONA P. RASALI, in partial fulfillment of the requirements for the degree of Master of Science (Animal Science) is hereby accepted.

ORLANDO A. PALAD
Member, Guidance Committee

6-4-91
Date Signed

SANTIAGO M. ALVIAR
Member, Guidance Committee

6/5/91
Date Signed

ANGEL L. LAMBIO
Member, Guidance Committee

6/4/91
Date Signed

FRANCISCO F. PEÑALBA
Adviser and Chairman
Guidance Committee

6/5/91
Date Signed

Accepted as partial fulfillment of the requirements for the degree of Master of Science (Animal Science).

FRANCISCO F. PEÑALBA
Director
Institute of Animal Science

6/5/91
Date Signed

NOEL G. MAMICPIC
Dean, Graduate School
University of the Philippines at Los Baños

6/7/91
Date Signed

BIOGRAPHICAL SKETCH

The author, the eldest son of Mr. Dhan Bahadur Rasali and Mrs. Sumitra Rasali, was born in Humin Jalpanagar of Palpa district in Nepal on June 3, 1954.

He attained his primary and subsequent secondary education in various schools in his home district until he joined Padmodaya High School in Kathmandu, Nepal for his tenth class in 1971. He stood Board first in the School Leaving Certificate (S.L.C.) Examination of Nepal in 1972, for which he was awarded the Kamala Gold Medal.

He passed the Intermediate in Science (I.Sc.) Examination, from Amrit Science College, Tribhuwan University, Kathmandu, Nepal in 1974 and then he was awarded a Colombo Plan scholarship to study veterinary medicine and animal husbandary in India. He graduated from the University of Agricultural Sciences, Bangalore, India in 1980, with the degree of Bachelor of Veterinary Science (B.V.Sc.).

Soon after obtaining his B.V.Sc. degree, he joined the then Department of Livestock Development and Animal Health, His Majesty's Government of Nepal, as Veterinary Officer (class III). Ever since 1980, he has been actively involved in the planning and execution of programs related to the delivery of livestock services including animal health care and animal breeding extension. During the past

period of his service in the department (now, the Department of Livestock Services) he had attended a few in-service trainings and study tours on the various fields including rural development planning, veterinary pathology and buffalo reproduction abroad particularly in Thailand, Australia, Malaysia and India.

Later in 1988, he was awarded a United States Agency for International Development scholarship and a study leave to pursue graduate study in animal breeding leading to Master of Science (M.S.) degree at the University of the Philippines at Los Baños (UPLB).

The author is a life member of Nepal Veterinary Association and also a life-time member of the Philippine Society of Animal Science. On the basis of his high scholastic record in his graduate study at UPLB, he has been elected a member of the Phi Sigma Biological Science Honor Society this year.

The author has four research papers to his credit including the one published in an international refereed journal.

He is happily married to Krishna with whom he is blessed with a daughter, Rubina and a son, Prabin.

DRONA P. RASALI

ACKNOWLEDGEMENT

The author wishes to express his heartfelt gratitude and profound appreciation to the following persons/ entities who have directly or indirectly contributed to the accomplishment of this work:

His adviser and chairman of the guidance committee, Dr. Francisco F. Peñalba, Assistant Professor and Director, Institute of Animal Science (IAS), UPLB for his invaluable advice, suggestions, guidance, encouragement and all kinds of help during his graduate study in general and the thesis work in particular;

Members of his guidance committee, Dr. Angel L. Lambio, Assistant Professor and Deputy Director, IAS, UPLB for his teachings through his courses in animal breeding and genetics and his invaluable suggestions, advice and encouragement during this study; Prof. Orlando A. Palad, Associate Profesor, IAS, UPLB for his teachings, invaluable suggestions and encouragement during this study; and Dr. Santiago M. Alviar, Associate Professor of Statistics and Computer Science and Vice-chancellor for Planning and Development, UPLB for his invaluable suggestions and encouragement during this study;

Dr. Valentino G. Arganosa, Professor, IAS, UPLB for his inspiring contribution to the Philippine swine industry and to the field of swine genetics and breeding;

Drs. B.A. Parker, Professor of Animal Breeding, V.G. Momongan, Professor of Animal Physiology, P.F. Alcantara, Associate Professor of Animal Production, I.G. Lumanta and B.A. Oliveros, Assistant Professors of Animal Nutrition, N.P. Roxas and S.S. Capitan, Assistant Professors of Animal Physiology and all other teachers under whom the author has taken courses during his graduate study, for their teachings which were in support of this work;

Mr. Nanda Shrestha, the Manager of Lampatan Livestock Farm, Pokhara, Nepal, who is also presently a graduate student at UPLB, for his hardwork in maintaining swine breeding records in the farm and generously allowing access to the farm records for use in the first part of this work;

Mr. Dan B. Singh and Mr. Bhim B. Gurung, Livestock Officers and other staff members at Lampatan Livestock Farm, Pokhara, Nepal for their cooperation;

Dr. Marry Ann Sayoc, Project Manager, International Training Center on Pig Husbandary (ITCPH), Lipa City, Batangas Province, for her permission to conduct on-farm testing of pigs at ITCPH farm;

Mr. Gabriel Katigbak, the ITCPH Farm Manager, for his cooperation in the study conducted at his farm and his helpful arrangement of the author's accomodation during the study period;

Mr. Victor Endaya, Mr. Tomas Buizon, Dr. Erden Evangelista, Dutch expatriate team and all other ITCPH staff including the farm personnels for their cooperation in the study;

Alberto Eusebio for his computer programming and assistance in the analyses of data;

Data Consultant Service, Muntinlupa, Metro-Manila for providing their survey information on prices of pork commodity and production inputs;

His Majesty's Government of Nepal for awarding a scholarship to the author and granting him the study leave for his graduate study at UPLB;

Acting Secretary Dr. Heramba B. Rajbhandary, Ministry of Agriculture, Nepal, the present and former Director-Generals Mr. Kedar Raj Pandey and Dr. Uday Singh, Deputy Director-Generals Dr. Bhawanada Thakur and Mr. Nitya Dhoj Joshi and Regional Director Mr. Ram Milan Upadyay, Department of Livestock Services, Nepal for their great encouragement and moral support;

United States Agency for International Development (USAID), Nepal/ Manila for sponsoring the scholarship under Agricultural Research and Production Project, Nepal to support the author's graduate study at UPLB;

Winrock International staff at Kathmandu and Manila for their helpful cooperation during their management of

the author's scholarship for most period of his graduate study from the beginning;

All Nepali friends in Los Banos including Mohan Kharel, Nanda Shrestha, Bir Thapa, Rama Bhurtel, Durga Dhakal, Mahesh Sapkota, Rishi Adhikari, Resham Thapa, Krishna Shrestha, Dr. Jit "Bhuktan", Bishnu Puri, Nir Jirel, Laxman Pun, Khem Sharma and their family members for their cooperation and efforts in making together a happy community in the Philippines; and

Melanie, Mrs. Ibarra, Cinta, Guen, Atisol at IAS, UPLB for their cooperation.

The author is deeply indepted to his beloved parents, all brothers and sisters, grand father, all uncles and aunties, father-in-law, mother-in-law, all other in-laws and other relatives for their inspirations, sacrifices and well-wishings.

Finally, the author wishes to express his profound gratitude to his wife Krishna for her love, understanding, sacrifices, conscience keeping and all the help she has offered to enable him to bring this work to completion; and to his two little children, Rubina and Prabin for their love and sharing of all feelings in a home abroad.

This work is dedicated to.....

The author's grand parents:

LATE SRI DAMBAR S. RASALI,
LATE SMT. SETI RASALI,
SRI MAN B. GAHATRAJ
and
LATE SMT. ISHWORI GAHATRAJ.

TABLE OF CONTENTS

Chapter		Page
I	INTRODUCTION	1
	Objectives of the study	4
II	REVIEW OF LITERATURE	6
	Litter Performance Traits	6
	Litter Size at Birth	6
	Litter Birth Weight	8
	Litter Size at Weaning	9
	Percentage Weaning of Total Pig Born	11
	Litter Weaning Weight	11
	Average Pig Weaning Weight	12
	Heritability Estimates	13
	Litter Size at Birth	14
	Litter Birth Weight	15
	Litter Size at Weaning	16
	Percentage Weaning of Piglets	17
	Litter Weaning Weight	18
	Average Pig Weaning Weight	19
	Genetic Correlations	20
	Phenotypic Correlations	23
	Growth Performance Traits	27
	Philippine Data	30

Chapter		Page
	Heritability Estimates	33
	Average Daily Gain	33
	Feed Conversion Ratio	35
	Backfat Thickness	36
	Correlations of Traits	39
	Phenotypic Correlations	39
	Genetic Correlations	40
	Selection Index	41
III	MATERIALS AND METHODS	47
	Study I: Litter Performance Traits	47
	Source of Experimental Data	47
	Statistical Procedures	49
	Experimental design	49
	Estimation of Heritabilities	51
	Correlations of Traits	53
	Economic Values of Traits	56
	Selection Index	58
	Study II: Growth Performance Traits	62
	Management of Experimental Animals	62
	Experimental Data	63
	Statistical Procedure	65
	Phenotypic Parameters	65
	Genetic Parameters	66

Chapter		Page
	Economic Values of Traits	67
	Selection Index	69
	Analysis of Data	70
IV	RESULTS AND DISCUSSION	71
	Study I: Litter Performance Traits	71
	Means and Standard errors	71
	Heritability estimates	74
	Genetic Correlations	80
	Phenotypic Correlations	84
	Variances and Covariances	88
	Relative Economic Weights	92
	Selection Indices	95
	Study II: Growth Performance Traits	97
	Means and Standard errors	97
	Phenotypic Correlations	98
	Variances and Covariances	100
	Production Function	104
	Economic Values of Traits	107
	Selection Index	111
V	SUMMARY AND CONCLUSION	113
	LITERATURE CITED	118
	APPENDICES	133

LIST OF TABLES

Table		Page
1	Summary of heritability estimates for post weaning daily gain, based on paternal halfsib correlation.	34
2	Summary of heritability estimates of live backfat thickness based on halfsib correlation.	38
3	Analysis of variance for nested classification of litter performance traits (Illustration).	52
4	Analysis of covariance for nested classification of litter performance traits (Illustration).	54
5	Least square means (LSM) and standard errors (SE) of Litter performance traits in the swine herd in Nepal.	73
6	Heritability estimates and standard errors of different litter performance traits in the swine herd in Nepal.	77
7	Phenotypic and genetic correlations among litter performance traits in the swine herd in Nepal.	90
8	Phenotypic variances and covariances among litter performance traits in the swine herd in Nepal.	91
9	Genetic variances and covariances among litter performance traits of the swine herd in Nepal.	91
10	Relative economic weights of selected litter performance traits in the swine herd in Nepal.	95
11	Swine Selection indices and their relative efficiencies for selected litter performance traits in the swine herd in Nepal.	96

Table		Page
12	Least square means and standard errors of production variables in on-farm tested Nieuw Dalland pigs.	98
13	Phenotypic (Perason's) correlations of ADG, FCR and BFT in on-farm tested Nieuw Dalland pigs.	101
14	Phenotypic variances and covariances of ADG, FCR and BFT in on-farm tested Nieuw Dalland pigs.	101
15	Literature estimates of heritabilities and genetic correlations of ADG, FCR and BFT in three breeds of pigs combined.	103
16	Genetic variances and covariances of ADG, FCR and BFT for on-farm tested Nieuw Dalland pigs, computed on the basis of genetic parameters reported by Lambio et al. (1986).	103
17	Average values of producer supplied inputs of production function and output of Nieuw Dalland market hogs.	106
18	Comparative data on relative economic weights of ADG, FCR and BFT across various studies.	110

LIST OF APPENDIX TABLES

Appendix Table		Page
1	Number of observations of litter performance traits by different categories of sire, dams, litters and their breeds groups.	133
2.1	Least square Analysis of variance for LSB.	134
2.2	Least square Analysis of variance for LBW.	134
2.3	Least square Analysis of variance for LSW.	135
2.4	Least square Analysis of variance for PWT.	135
2.5	Least square Analysis of variance for LWW.	136
2.6	Least square Analysis of variance for AWW.	136
3.1	Analysis of covariance for LSB and LBW.	137
3.2	Analysis of covariance for LSB and LSW.	137
3.3	Analysis of covariance for LSB and PWT.	137
3.4	Analysis of covariance for LSB and LWW.	138
3.5	Analysis of covariance for LSB and AWW.	138
3.6	Analysis of covariance for LBW and LSW.	138
3.7	Analysis of covariance for LBW and PWT.	139
3.8	Analysis of covariance for LBW and LWW.	139
3.9	Analysis of covariance for LBW and AWW.	139
3.10	Analysis of covariance for LSW and PWT.	140
3.11	Analysis of covariance for LSW and LWW.	140
3.12	Analysis of covariance for LSW and AWW.	140
3.13	Analysis of covariance for PWT and LWW.	141

Appendix Table		Page
3.14	Analysis of covariance for PWT and AWW.	141
3.15	Analysis of covariance for LWW and AWW.	141
4	Step-wise regression analysis of PWT and AWW of the litter production function on litter output (LSW) using backward elimination procedure.	142
5	Step-wise regression analysis of LSB and LBW of the litter production function on litter output (LSW) using backward elimination procedure.	144
6	Assumptions of technical coefficients for computation of cost of production of a on-farm tested Nieuw Dalland market hogs.	146
7	Regression analysis of production function of final weights (FWT) of marketable Nieuw Dalland hogs (Before removing non-significant variabes).	148
8	Regression analysis of production function of final weights (FWT) of marketable Nieuw Dalland hogs (Final model).	149

ABSTRACT

RASALI, DRONA PRAKASH, University of the Philippines at Los Baños, June, 1991. Genetic, Phenotypic and Economic Parameters for Construction of Swine Selection Indices: Cases of Nepal and the Philippines.

Major Professor: Dr. Francisco F. Peñalba

Performance records of a total of 147 litters, farrowed in five years by 59 sows and sired by seven boars of Landrace, Yorkshire and their crosses in a Government owned farm in Nepal were analysed. Results showed that the least square means and standard errors (S.E.s) of litter size at birth (LSB), litter birth weight (LBW), litter size at weaning (LSW), percentage weaning of total pigs born (PWT), litter weaning weight (LWW) and average pig weaning weight (AWW) were 9.435±0.272, 10.604±0.393 kg, 6.907±0.328, 75.296±2.838 %, 47.026±5.055 kg and 6.626±0.347 kg, respectively, while their heritability estimates based on sire component of variance were 0.102±0.193, 0.144±0.241, 0.232±0.179, 0.229±0.262, 1.172±0.926 and 0.409±0.462, respectively.

The genetic correlations among all the traits studied were generally positive and high with their estimates either exceeding unity or comparable with higher literature estimates. The phenotypic correlations were

positive and highly significant (P<0.01) among most of the traits except in some cases of PWT and AWW, of which both were negatively and significantly (P<0.05) correlated with LSB while only AWW was negatively and significantly (P<0.05) correlated with LSW. The relative economic weights for PWT-AWW and LSB-LBW trait pairs as estimated on the basis of a specified production function were found to be in the ratios of 1.00: -4.21 and 2.71: 1.00, respectively.

Two selection indices constructed using these parameters for the two pairs of traits were: I = 0.033(PWT) + 0.255(AWW) and I = 0.037(LSB) + 0.087(LBW), with their corresponding relative efficiencies of 25.88 and 21.20 %, respectively.

On the other hand, growth performance data on on-farm tested forty two barrows and twenty one gilts of a Nieuw Dalland commercial herd in the Philippines were analysed. Results showed that the least square means and S.E.s of average daily gain (ADG), feed conversion ratio (FCR) and backfat thickness (BFT) were 0.686±0.013 kg, 2.823±0.060 and 1.583±0.041 cm, respectively. A positive and highly significant (P<0.01) phenotypic correlation was evident between ADG and BFT, both of which, in turn, were found to have negative and highly significant (P<0.01) correlation with FCR. The relative economic weights of ADG, FCR and

BFT estimated on the basis of a highly fitting model of a specified production function were 6.24, -9.08 and 1.00, respectively.

A selection index constructed using these parameters for the three traits and also the literature estimates of their genetic parameters was: I = 200 +42.56(ADG) -20.78(FCR) -6.82(BFT), with its relative efficiency of 52.05 %.

INTRODUCTION

Several economic traits expressed by a pig during its life time have a direct bearing on its overall productivity influencing the profitability of a swine enterprise. Most important of them all are those related to reproductive and growth efficiencies. Among the reproductive traits, the litter performance traits usually observed in the litters from their birth to weaning as the consequence of the parental reproductive ability are of paramount importance to breeders whose major interest lies on securing maximum number of pigs weaned per sow per year. On the other hand, growth performance traits observed later in the life of an individual pig are related to the pig's growth rate, production efficiency and carcass desirability and have been increasingly important in the modern pork production system. Both sets of these traits have to be considered in the efforts of improving pigs through breeding with the objective of progressively optimising their overall productivity.

Selection is one of the key ways in which the breeder can change the genetic properties of a pig population in his efforts of improving the economic traits towards the desirable directions. The optimal procedure for selection is to use all the information available about the breeding value of each individual (Falconer, 1981). When the

breeder is confronted with two or more economically important traits to be considered, selection strategy becomes complex. In this situation, combining all the information into a selection index on the basis of which the individuals are selected is the most efficient method of selection (Hazel and Lush, 1942).

Index selection has been a common method used by swine breeders in the advanced countries, who are selecting for more than one economic trait at a time. However, its use in the developing countries particularly in Asia has been extremely limited due to the fact that wide-scale genetic evaluation of the swine stocks and formulation of appropriate criteria for their selection suited to the local conditions are still lacking. The cases in Asian context can be described in two categories of countries as typically and distinctly exemplified by Nepal and the Philippines with varying levels of production efficiencies.

In the case of Nepal, the swine production is limited to smallholder farms mostly as supporting enterprises of the subsistence farmers and the only definite sources of improved breeding animals are the government owned farms. No attempts of genetic evaluation including the estimation of genetic parameters in the swine stocks and formulation of appropriate selection criteria have been made so far.

There is apparently a need, at the present stage, to conduct genetic evaluation and formulate selection criteria at least for the litter performance traits which have been given considerable importance in the country.

On the other hand in the Philippines, swine production which is a major livestock industry largely under the small-holder production system constituting at least 79% of the yearly total swine populations (Peñalba, 1986b), has gone a way ahead also in the commercial production especially to meet urban demands. Some studies on genetic evaluation including estimation of genetic parameters and formulation of a few selection indices (Puyaoan, 1971; Pham, 1972; Arganosa et al., 1974/75; Lambio et al., 1986; Lambio et al., 1990a and 1990b) have also been made. On-farm performance testing using a selection index for selection of pigs for breeding herd replacements has been a feature in many commercial farms. Since 1988, an on-station testing scheme known as National Swine Performance Testing Program (NSPTP) has been implemented as described by Peñalba (1989). Nevertheless, the selection index presently used in the performance testing was developed in Iowa Testing Station in the United States and its suitability under the Philippine conditions is largely unknown. A considerable risks can exist in using such an index of foreign origin

particularly due to differences in economic values of the traits considered (Chyr, 1980).

Hence, upon realizing the current need of most important considerations to be made in swine breeding in these two countries, genetic, phenotypic and economic parameters for formulation of selection indices for litter performance traits in a Nepalese swine herd and formulation of a selection index for growth performance traits in a commercial swine stock in the Philippines were investigated in the present work.

Objectives of the Study

The present work was undertaken for a case each of Nepal and the Philippines in separate studies to fulfill the following specific objectives:

1. To determine phenotypic parameters, namely means and standard errors, phenotypic correlations, variances and covariances among the litter size at birth (LSB), litter birth weight (LBW), litter size at weaning (LSW), percentage weaning of total pigs born (PWT), litter weaning weight (LWW) and average pig weaning weight (AWW) in a pig herd in Nepal.

2. To determine genetic parameters, namely heritabilities, genetic correlations, variances and

covariances among LSB, LBW, LSW, PWT, LWW and AWW in the herd in Nepal.

3. To determine relative economic weights of the selected litter performance traits in the pig herd in Nepal.

4. To construct selection indices for the selected litter performance traits in the pig herd in Nepal.

5. To determine phenotypic parameters, namely means and standard errors, phenotypic correlations, variances and covariances among average daily gain (ADG), feed conversion ratio (FCR) and backfat thickness (BFT) in Nieuw Dalland hogs in a herd in the Philippines.

6. To determine genetic variances and covariances of ADG, FCR and BFT in the herd in the Philippines based on literature estimates of their heritabilities and genetic correlations.

7. To determine relative economic weights of ADG, FCR and BFT in the herd in the Philippines.

8. To construct a selection index using ADG, FCR and BFT for on-farm performance testing of the commercial hogs in the Philippines.

REVIEW OF LITERATURE

Litter Performance Traits

Litter Size at Birth

Among a number of litter performance traits in swine, litter size has been the most economically important trait reported (Smith et al., 1983) and has been most widely studied due to a tremendous opportunity to improve the overall efficiency of swine production that can be offered by improvement of this trait (Peñalba, 1986a) and also due to the ease in its recording (Haley et al., 1988).

Litter size at birth (LSB) usually measured as total number of pigs born has been studied by numerous workers on varying sizes of the populations. Omtvedt et al. (1966) reported that number of pigs farrowed per litter in 155 sow litters and 298 gilt litters were 11.2±3.0 and 10.1±2.8 with an overall mean of 10.6. Vangelov (1970) reported an average litter size at birth of 10.07 in a population of 10,308 pigs. Nikolic et al. (1970) reported that average figures for 211 and 303 litters of two dam groups were 10.95 and 11.02, respectively, whereas those for 411 and 422 litters of their corresponding daughter groups were 10.75 and 10.64, respectively.

In a pedigreed herd in Russia, the average litter size at birth was 9.48 for first litters and 10.41 for

first 3 litters (Silvinskaya, 1974). Other studies in Russia, Bulgaria and Yugoslavia revealed that the average figures of litter size at birth in different pig populations were in the range of 10-11.4 (Belic et al., 1975; Gorin et al., 1976b; Andreev et al., 1979; Venev, 1981; Minutin and Svechin, 1981 and Jancic et al., 1982a) which were consistent to the average figures, 10.40±0.3 reported for 3 breeds, Duroc, Landrace and Yorkshire in the Philippines (Argañosa et al., 1974/75); 10.44±0.16 reported for crossbred male piglets in Korea (Rhee et al., 1987) and 10.21±0.08 reported for 2570 Large White litters in Brazil by Alves et al., (1989). Lambio et al. (1986) reported that litter size at birth in Yorkshire, Landrace, Duroc and combined breeds in the Philippines were 10.0±1.0, 10.1±1.0, 8.7±1.0 and 9.8±1.0, respectively. Average figures of litter size at birth, between 9 and 10.4 were also reported in Canada by Fahmy and Bernard (1972a and 1972b), from Brazilian data by Irgang and Robison (1984), in Yugoslavia by Stankovic (1977) and Jancic et al. (1980a and 1980b), in Korea by Park et al. (1987) and in Landrace and Duroc breeds in Brazil by Alves (1989). Wu and Zhang (1983) reported in China that 3 old established breeds, Taihu, Asia and Large spotted gave births to 16.1, 15.3 and 13.3 piglets on average, respectively. On the other hand, low litter sizes at birth

in modern breeds were reported in India with average figures of 7.8±0.26, 8.4±0.27 and 8.5±0.48 in 55 Landrace, 52 Landrace x Large White and 12 Large White litters, respectively as reported by Deo et al., (1980) and 8.91 in 127 litters as reported by Gupta et al. (1983b). Recently, similar average figures, 9.28, 7.91 and 8.83 were reported in Landrace, Yorkshire and Landrace x Yorkshire crosses in Nepal (Shrestha and Gurung, 1989).

Litter Birth Weight

Many workers have studied the weight of litter at birth that is largely dependent on litter size. Omtvedt et al.(1966) reported that means of litter weight at birth in 155 sow litters and 298 gilt litters and their overall mean were 14.8±3.5, 12.4±3.2 and 13.5 kg, respectively. Fahmy and Bernard (1972a and 1972b) reported the mean values, 9.40±2.76 and 9.26±0.24 for the trait in Yorkshire gilts and 751 other Yorkshire gilts of 3 selected lines, respectively. Vangelov (1970) reported the mean value of the trait to be 12.47 for a population of 10,309 pigs. The mean value of the trait with its standard error in 737 litters of Duroc, Landrace and Yorkshire in the Philippines as reported by Argañosa et al. (1974/75) was 11.54±0.15 which was similar to the mean value of the trait, 11.5 in Taihu breed in China with large litter size

(Zhang, 1983). Young et al. (1978) reported an average of litter birth weight to be 12.6±3.7 for Nebraska gene pool herd. Recent report from Brazil revealed that the litter birth weight in 3416 Landrace, 2570 Large White and 687 Duroc litters averaged 15.80±0.11, 16.0±0.12 and 14.70±0.19, respectively (Alves et al. (1989).

Records of Lampatan Livestock Research Station in Nepal showed that Landrace had heavier litter than Landrace x Yorkshire cross or Yorkshire with their litter birth weights, 10.66±3.1, 10.04±2.8 and 9.59±3.01, respectively (Anonymous, 1988).

Litter Size at Weaning

Total number of pigs weaned has been another important litter performance trait widely studied by numerous workers. Omtvedt et al. (1966) reported that the number of pigs weaned per litter at 42 days in 155 sow litters and 298 gilt litters were 8.4±2.4 and 8.3±2.4 with the overall mean of 8.3. Strang (1970) found that number of pigs at 3 weeks and number of pigs at 8 weeks in 38,000 Large White litters averaged 9.0±2.3 and 8.8±2.3, respectively. Fahmy and Bernard (1972a and 1972b) have reported averages for number of pigs weaned at 56 days as 7.09±2.50 and 6.82±0.10 in 704 Yorkshire gilts litters and 751 litters of 3 lines of Yorkshire gilts, respectively.

NAAC Lib.
NR-869

Similarly, Vangelov (1970) reported the litter size at weaning at 60 days in 10,309 pigs to be 8.71, whereas that weaned at 56 days in 2826 litters, as reported by Belic et al. (1975) was slightly higher averaging 9.29. The litter size at weaning at 35 days in a commercial farm in the Philippines was reported to be 7.70±0.12 (Argañosa et al., 1974/75). The number of pigs weaned at 42 days in the litters of Nebraska gene pool synthetic population was 7.6±2.4 (Young et al., 1978). In 55 Landrace, 52 Landrace x Large White and 12 Large White litters in India, the trait averages were 5.41±0.28, 6.1±0.26 and 7.2±0.56, respectively (Deo et al., 1980). Subsequently, other workers (Jancic et al., 1980b; Jancic et al. 1982a; Gupta et al., 1983a; Park et al., 1987 and Rhee et al., 1987) have also reported similar averages of the traits all falling within the range of 6.8 to 8.5. A recent report on 3416 Landrace, 2570 Large White and 687 Duroc litters in Brazil revealed the trait averages of 8.96±0.05, 9.21±0.07 and 8.21±0.10, respectively (Alves et al., 1989). Average litter sizes at weaning for pigs maintained at Lampatan livestock Farm and 8 smallholder farms in Pokhara, Nepal. were 7.02±3.12 and 6.93±2.01, respectively (Anonymous, 1988).

Percentage Weaning of Total Pigs Born

A very few reports are avaliable for the percentage weaning of total pigs born (PWT) as a trait measurement. Argañosa et al. (1974/75) reported PWT in Duroc, Landrace and Yorkshire pigs to be 79.5±0.77. Averages of the trait in two commercial herds in the Philippines were 82.06±2.27 and 79.52±1.82 as reported recently by Argañosa et al. (1990a and 1990b), respectively.

Litter Weaning Weight

Litter weaning weight is determined to a greater extent by variations in the number of pigs in the litter at weaning than by variations in pig weaning weight. Since this trait is a function of both prolificacy and maternal ability, it is considered the best single measure of sow productivity (Omtvedt et al., 1966) and it has been studied by several workers. Omtvedt et al. (1966) have reported that litter weaning weights at 42 days in 155 sow litters and 288 gilt litters were 103.5±25.3 and 88.6±22.7 kg, respectively with an overall mean of 95.3 kg. Strang (1970) reported that 8 week mean litter weight in 38,000 litters was 317.2±108.6 lb. Fahmy and Bernard (1972a and 1972b) have reported mean litter 56-day weights in 704 litters of Yorkshire gilts and 751 gilt litters of 3

Yorkshire lines, to be 92.68±36.20 and 92.58±3.18 kg, respectively. Vangelov (1970) reported that the litter weight at 60 day weaning in 10,309 pigs was 132.62 kg. Deo et al. (1980) reported that average weaning weights of litters in 55 Landrace, 52 Landrace x Large White and 12 Large White litters were 59.5±0.24, 55.4±2.88 and 48.2±4.87 kg, respectively. Similarly, mean of litter weight at 35 day weaning was reported to be 48.09±0.71 in the Philippines (Argañosa et al., 1974/75). Jancic et al. (1980b and 1982b) have reported that the trait averages were 35.98 and 39.18±0.36 kg, respectively at 21 day's weaning, whereas the weights of litters at 30 day's weaning reported by Park et al. (1987) averaged 70.7±0.06 kg.

Average Pig Weaning Weight

Pig weaning weight has been studied by several workers either on the basis of individual pig weight or average pig weight in the litter. Omtvedt et al. (1966) reported that 155 sow litters and 298 gilt litters had mean pig weaning weights of 12.8±2.3 and 11.0±1.9 kg, respectively with an overall mean of 11.8 kg, whereas Strang (1970) reported that means of average pig weights in the litters at 3 weeks and 8 weeks were 13.1±2.4 and 37.0±10.0 lb, respectively. Least square means of pig

weaning weight reported by Fahmy and Bernard (1972a) was 13.50±2.55 kg. The mean of average pig weaning weights at 35 days in a commercial farm in the Phililppines was 6.27±0.07 kg (Argañosa et al., 1974/75). Young et al., (1978) reported that gilts weaned at approximately 42 days of age averaged 12.86±1.81 kg at weaning, whereas weaning weights in male pigs and female pigs at 56 days averaged 12.04 and 12.00 kg, respectively in India (Bhatia and Sharma, 1979). Jancic et al. (1980b) reported average of piglet weights in litters of 174 sows to be 4.70 kg at 21 days which was consistent with the piglet weaning weight of 4.67±0.04 averaged over 1 to 5 litters reported by Jancic et al. (1982a). Based on the records of 422 male and 373 female piglets born, Gupta et al. (1983a) found that their mean pig weights at 8 weeks were 11.20±0.13 and 10.74±0.09 kg, respectively.

Heritability Estimates

Heritability describes the proportion of genetic variation in the observed variation of a trait (Cunningham, 1969b). The knowledge of heritability estimate of any economic trait is very helpful in choosing an efficient breeding system and in estimating the amount of response to selection (Kempthorne and Tandon, 1953), since the effectiveness of selection depends largely on

the magnitude of heritability of the traits. Numerous estimates of heritability for some litter performance traits are available in the literature, while for others estimates are still lacking or scarce and most papers provide such information on only few traits (Young et al., 1978).

Litter size at birth. Numerous studies reported so far have confirmed the generally low heritability of litter size. However, several other reports of a wide range of heritability estimates have appeared in the literature due to the genetic and environmental differences in the populations studied and also because of large sampling errors. Several workers (Edwards and Omtvedt, 1970; Polyanichko, 1973; Walker et al., 1973; Gorin et al., 1976a; Andreev et al., 1979; Jancic et al., 1980b; Zhang, 1983; Johansson, 1983; Triebler, 1989 and Zschorlich and Ritter, 1989) reported the heritability estimates of total number of pigs born that ranged from practically 0 to 0.10 in varying kinds of pig populations. Vangelov (1970), Kryatov (1972), Gajic (1974), Silvinskaya (1974), Popescu-Vifor (1975), Belic et al. (1975), Argañosa et al. (1974/75), Gorin et al. (1976b), Baik et al. (1977), Eliseev and Strelkova (1977), Valarezo and Quijandria (1979), Venev (1981), Silver and Pavlik (1982), Milagres et al. (1983), Park and Kim (1987), Chung and

Park (1987), Alves et al. (1989), Kim et al. (1989), Moskvin (1989), and Fonseca et al. (1989) reported the heritability estimates of total number of pigs born within the range of 0.10 to 0.20, while some other workers (Nikolic et al., 1970; Irvin, 1976; Jancic et al., 1980a; Asling et al., 1980; Minutin and Svechin, 1981; Schlindwein and Duarte, 1981; Toelle and Robison, 1986; Park and Kim, 1987; Park et al., 1987; Kim et al., 1989 and Moskvin, 1989) have reported slightly higher estimates for the trait within the range of 0.20-0.30. Schlindwein et al. (1980) reported even a negative value of heritability of the trait estimated in 691 litters based on half sib correlation. On the other hand, Stankovic (1977), Chantsavang (1977) and Young et al. (1978) have reported high estimates of 0.51, 0.54 and 0.72 in sizable populations, respectively. Nevertheless, in a comprehensive review based on the findings from the large European pig populations, Haley et al. (1988) have conclusively reported that litter size has a heritability estmate of around 0.10.

Litter birth weight. Heritability estimates of litter birth weight also varied widely in the reported literature. Some workers reported estimates as low as zero (Polyanichko, 1973) and even a negative value

(Schlindwein et al., 1980), while many others have reported estimates falling within the range of 0.01 to 0.10 (Gajic, 1974 and Baik et al., 1977), but numerous other workers reported the estimates for litter birth weight to be in the range from 0.10 to 0.30 (Vangelov, 1970; Edwards and Omtvedt, 1970; Walker et al., 1973; Gajic, 1974; Belic et al., 1975; Argañosa et al., 1974/75; Vidovic, 1979; Zhang, 1983; McCarter et al., 1987; Alves et al., 1989 and Zschorlich and Ritter, 1989). Park and Kim (1987) and Kim et al. (1989) have reported similar estimates with the values for Landrace, Yorkshire, Duroc and Hampshire being 0.32±0.11, 0.32±0.13, 0.23±0.13 and 0.09±0.10, respectively. However, on the other hand, Irvin (1976), Acta Genetica Sinica (1977), Irvin and Swiger (1977), Chantsavang (1977) and Schlindwein and Duarte (1981) have reported estimates as high as 0.54, 0.44, 0.54, 0.77 and 0.46, respectively.

Litter size at weaning. Numerous heritability estimates of litter size at weaning (LSW) have been reported in the literature. Most published estimates were generally very low ranging from practically zero (Gupta et al., 1983b and Fonseca et al., 1989) to around 0.10 (Strang and King, 1970; Gajic, 1974; Stankovic, 1977 and Chung and Park, 1987) with several other estimates falling within this range (Nikolic et al., 1970; Jancic et al.,

1980b; Johansson, 1983 and Milagres et al., 1983) irrespective of the weaning ages at which the estimates of heritability was obtained. However, there were also several moderate estimates reported in the range between 0.10 and 0.30 (Vangelov, 1970; Walker et al., 1973; Argañosa et al., 1974/75; Irvin, 1976; Acta Genetica Sinica, 1977; Irvin and Swiger, 1977; Éliseev and Strelkova, 1977; Valarezo and Quijandria, 1979; Jancic et al., 1980a; Zhang, 1983; Park et al., 1987; Alves et al., 1989 and Kim et al., 1989). Some authors (Mahmud, 1970; Chantsavang, 1977 and Schlindwein and Duarte, 1981) have reported even higher estimates but not exceeding 0.40.

Percentage weaning of piglets. A few number of published reports on heritabilities of traits associated with weaning perecentage is available. The heritability estimates for percentage of weaning reported by Argañosa et al. (1974/75) were 0.37 based on total pigs born and 0.34 based on live born pigs, which were very close to 0.40 as the heritability estimate for survival rate from birth to 8 weeks of age reported by Cummings et al. (1947). On the other hand, Park et al. (1987) reported a lower heritability estimate, 0.12±0.17 for the survival rate to weaning.

Litter weaning weight. Heritability estimates of litter weights at weaning have been available abundantly in the literature. Although there was a general tendency for the traits involving weight to have higher heritability than those for litter number or mortality (Strang and Smith, 1979), a wide range of heritability estimates of the traits involving weight has been reported.

Several workers (Strang and King, 1970; Kryatov, 1972; Jancic et al., 1980a and Kim et al., 1989) reported very low heritability estimates for litter weaning weight, between 0.01 and 0.10. Fahmy and Bernard (1972b), Strang and King (1970) and Irvin (1976) reported the estimates to be even negative values, -0.12±0.26, -0.02±0.04 and -0.01, respectively.

On the other hand, the heritability estimates of litter weight at weaning reported by most of the other numerous workers (Vangelov, 1970; Edwards and Omtvedt, 1970; Walker et al., 1973; Argañosa et al., 1974/75; Belic et al., 1975; Acta Genetica Sinica, 1977; Irvin and Swiger, 1977; Chantsavang, 1977; Popescu-Vifor, 1977; Young et al., 1978; Milagres et al., 1983; and McCarter et al., 1987) ranged from 0.10 to 0.30. Furthermore, the heritability estimates of the trait were also as high as 0.43, 0.80 and 0.72 reported by Eliseev and Strelkova

(1977), Minutin and Svechin (1981) and Schlindwein and Duarte (1981), respectively. Fahmy and Bernard (1972b) presented the best heritability estimate for the trait to be 0.14 while 5 estimates from other literature cited by them ranged from 0.07 to 0.28. Similarly, Young et al. (1978) cited literature estimates from 16 other studies in the range from 0.01 to 0.33 with an average of 0.13 for weight of litter weaned at 42 or 56 days. Similar literature estimates were also cited by Strang and Smith (1979).

Average pig weaning weight. Heritability estimates of weight of pigs at weaning reported in the literature on the basis of either individual body weight or average pig weight in the litter also varied widely. Many workers (Vangelov, 1970; Strang and King, 1970; Valarezo and Quijandria, 1979; Bhatia and Sharma, 1979 and Fonseca et al., 1989) reported estimates in the range from zero to 0.10, while Popescu-Vifor (1975), Vasileva et al., (1978), Strang and Smith (1979), Milagres et al. (1983) and Park et al.(1987) reported estimates in the range of 0.1 to 0.30. Significantly higher estimates, 0.40±0.14, 0.43, 0.37±0.2 and 0.62±0.08 were reported by Argañosa et al. (1974/75), Acta Genetica Sinica (1977), Gupta et al. (1983a) and Strang and Smith (1979), respectively.

(1977), Minutin and Svechin (1981) and Schlindwein and Duarte (1981), respectively. Fahmy and Bernard (1972b) presented the best heritability estimate for the trait to be 0.14 while 5 estimates from other literature cited by them ranged from 0.07 to 0.28. Similarly, Young et al. (1978) cited literature estimates from 16 other studies in the range from 0.01 to 0.33 with an average of 0.13 for weight of litter weaned at 42 or 56 days. Similar literature estimates were also cited by Strang and Smith (1979).

Average pig weaning weight. Heritability estimates of weight of pigs at weaning reported in the literature on the basis of either individual body weight or average pig weight in the litter also varied widely. Many workers (Vangelov, 1970; Strang and King, 1970; Valarezo and Quijandria, 1979; Bhatia and Sharma, 1979 and Fonseca et al., 1989) reported estimates in the range from zero to 0.10, while Popescu-Vifor (1975), Vasileva et al., (1978), Strang and Smith (1979), Milagres et al. (1983) and Park et al.(1987) reported estimates in the range of 0.1 to 0.30. Significantly higher estimates, 0.40±0.14, 0.43, 0.37±0.2 and 0.62±0.08 were reported by Argañosa et al. (1974/75), Acta Genetica Sinica (1977), Gupta et al. (1983a) and Strang and Smith (1979), respectively.

Genetic Correlations

Genetic correlations among economic traits are one of the vital parameters needed to develop selection criteria such as selection indices for improving net merit with simultaneous considerations of several traits. There have been numerous estimates of genetic correlations for some traits or only for a few traits in most cases reported in the literature, while for others estimates are lacking (Young et al., 1978). This is particularly true among litter performance traits.

Numerous estimates of genetic correlations of litter size at birth with some of the other litter traits are available in the literature. The genetic correlation of litter size at birth (LSB) with the number of pigs weaned as reported by Argañosa et al. (1974/75), Chung and Park (1987), Park et al. (1987) and Rhee et al. (1987) were 0.80±0.17, 0.75, 0.54 and 0.69, respectively which were consistent with the estimate range from 0.52 to 0.86, reported recently by Alves et al. (1989). The estimates of genetic correlation between litter size at birth and litter birth weight, 0.70, 0.84, 0.63, 0.79 and 0.54 reported by Acta Genetica Sinica (1977), Baik et al. (1977), Milagres et al. (1983), Park and Kim (1987) and Fonseca et al. (1989), respectively were consistent with the large positive estimates reported by Chantsavang

(1977) and Young et al. (1978), while an estimate greater than unity was reported by Argañosa et al. (1974/75). Estimates of genetic correlation of litter size at birth with pig weaning weight on average in the litter or individual pig basis were negative but variable irrespective of weaning age among estimates which were -0.09±0.33, -0.64 and -0.60 as reported by Argañosa et al. (1974/75), Milagres et al. (1983) and Rico and Gomez (1983), respectively. Large positive genetic correlation of litter size at birth with litter weaning weight was shown by Chantsavang (1977), Young et al. (1978), Milagres et al. (1983) and Shi et al. (1987), while the estimate reported by Argañosa et al. (1974/75) was 0.48±0.35. Argañosa et al. (1974/75) estimated alsó genetic correlation of this trait with weaning percentage of total pigs born to be -0.17±0.36.

Genetic correlations of litter birth weight with litter size at weaning and litter weaning weight estimated by Argañosa et al. (1974/75) were greater than unity and were in agreement with those reported by Pham (1972) mainly due to large sampling errors. However, high and positive estimates for these two pairs of traits were reported by Kim et al. (1989). Similarly, a high estimate range from 0.52 to 0.86 for the pairs of traits was reported by Alves et al. (1989). Genetic correlations of

litter birth weight with pig weaning weight and weaning percentage of total pigs born with their corresponding standard errors estimated by Argañosa et al. (1974/75) were 0.48±0.29 and 0.25±0.36, respectively.

Genetic correlations of litter size at weaning with some other litter traits have also been estimated by various workers. The estimate of genetic correlation of the number of pigs weaned with average pig weaning weight at 8 weeks reported by Strang and King (1970) was high and negative, -0.6, while that with pig weaning weight with its standard error estimated by Argañosa et al. (1974/75) was 0.47±0.27. Genetic correlation between litter size at weaning and litter weaning weight varied considerably among estimates which were 0.30 at 8 weeks weaning, 0.99, 0.89 with the standard error of 0.10 and 0.55 at 21 days weaning, as reported by Smith and Strang (1970), Mahmud (1970), Argañosa et al. (1974/75) and McCarter et al. (1987), respectively. The genetic correlations of litter size at weaning with weaning percentage of total pigs born and pig weaning weight with their corresponding standard errors as estimated by Argañosa et al. (1974/75) were 0.53±0.26 and 0.47±0.27, respectively. The genetic correlation between litter size at 21-day and that at 56-day weaning as estimated by Schlindwein et al. (1982) was 0.99 indicating nearly a perfect genetic association.

The genetic correlation of average pig weight at 8 week weaning with litter weaning weight estimated by Strang and King (1970) and that of piglet weaning weight with litter weaning weight reported by Acta Genetica Sinica (1977) were consistent to each other with the estimates, 0.5 and 0.53, respectively, while much higher estimate of 0.80 with the standard error of 0.12 for the latter pair of traits was reported by Argañosa et al. (1974/75). Argañosa et al. (1974/75) estimated genetic correlation of pig weaning weight with weaning percentage of total pigs born to be very high, 0.87±0.06. Argañosa et al. (1974/75) also estimated very high genetic correlation of litter weaning weight with weaning percentage of total pigs born with the estimate and its corresponding standard error being 0.83±0.11.

Phenotypic Correlations

As the phenotypic correlation between any two economic traits measures the degree of their association influencing expression of each other, any selection scheme designed to improve one or more traits should also be effective in improving many other traits that are correlated (Fahmy and Bernard, 1972a). Phenotypic correlations like other parameters of some of the litter performance traits have been well documented, while

information on the correlations of many other traits of the litter are limited in the literature.

The phenotypic correlation between the litter size at birth measured as the total number of pigs born with that at weaning, as reported by Omtvedt et al. (1966), Edwards and Omtvedt (1971), Fahmy and Bernard (1972a), Pham (1972), Argañosa et al. (1974/75), Young et al. (1978), Chung and Park (1987) and Rhee et al. (1987) were high and positive in the range from 0.73 to 0.82, while a relatively lower estimate of correlation, 0.49 was also reported (Park et al., 1987). Large positive phenotypic correlation of the total number of pigs born with litter weight at birth in the range from 0.62 to 0.89 was observed by Edwards and Omtvedt (1971), Pham (1972), Fahmy and Bernard (1972a), Argañosa et al. (1974/75), Young et al. (1978) and Chung and Park (1987). Similarly, the phenotypic correlation of the trait with litter weaning weight in the range from 0.5 to 0.76 was reported by Omtvedt et al. (1966), Edwards and Omtvedt (1971), Pham (1972), Fahmy and Bernard (1972a) and Young et al. (1978), while a somewhat lower estimate of 0.44 was reported by Argañosa et al. (1974/75) falling in the estimate range from 0.21 to 0.52 reported by Gorin et al. (1976b). The phenotypic correlations of litter size at birth with percentage weaning of total pigs born and the pig weaning

weight either on individual or average weight basis have been reported in the literature as negative but varying in the range from low, r_p = -0.18 (Fahmy and Bernard, 1972a) to high, -0.52 (Argañosa et al., 1974/75) for the former pair of traits and also from low, r_p = -0.14 (Fahmy and Bernard, 1972a) to high, r_p = -0.59 (Omtvedt et al., 1966) with moderate estimates of -0.26, -0.25 and -0.36 reported by Revelle and Robison (1973), Argañosa et al. (1974/75) and Young et al (1978), respectively for the latter pair.

Phenotypic correlations of litter size at weaning (LSW) measured as the the total number of pigs weaned, with litter birth weight (LBW), litter weaning weight (LWW) and also with percentage weaning of total pigs born (PWT) reported in the literature were generally large and positive. The correlation estimates between LSW and LBW were in the range of 0.60 and 0.74 as reported by Omtvedt et al. (1966), Edwards and Omtvedt (1971), Fahmy and Bernard (1972a) and Pham (1972). The correlation between LSW and LWW appeared to follow similar trend but in a wider range from the estimate of 0.40 reported by Strang and King (1970) to the estimate of 0.88 reported by Fahmy and Bernard (1972a) with many other estimates falling in the range (Omtvedt et al., 1966; Edwards and Omtvedt, 1971; Argañosa et al. 1974/75 and McCarter et al., 1987). Pham (1972) reported an estimate for these traits to be

very low (r_p =0.05) largely due to sampling errors. The correlation estimates of LSW and PWT were 0.81, 0.53 and 0.52 as reported by Pham (1972), Fahmy and Bernard (1972a) and Argañosa et al. (1974/75), respectively.

The phenotypic correlation of litter birth weight (LBW) with LWW was highly significant ($P<0.01$) and positive among the estimates of 0.56, 0.69 and 0.52 reported by Omtvedt et al. (1966), Fahmy and Bernard (1972a) and Argañosa et al., (1974/75). On the other hand, the correlation of LBW with PWT was low negative and mostly non-significant with the estimates, -0.12, -0.02 and -0.01 reported by Omtvedt et al. (1966), Fahmy and Bernard (1972a) and Argañosa et al. (1974/75), respectively. Also, the published correlation estimates between LBW and AWW varied from either as very low as 0.04 (Fahmy and Bernard, 1972a) or low negative, r_p = -0.13 (Argañosa et al., 1974/75) to moderate negative, r_p = -0.35 (Omtvedt et al., 1966).

The phenotypic correlation between PWT and LWW was high and positive with very consistent estimates of 0.57, 0.52 and 0.55 reported by Omtvedt et al. (1966), Fahmy and Bernard (1972a) and Argañosa et al. (1974/75), respectively. Moderately high positive correlation of 0.34 between PWT and pig weaning weight was reported (Argañosa et al., 1974/75), whereas the correlation estimate of pig

weaning weight with the survival rate to weaning as reported by Omtvedt et al. (1966) and Fahmy and Bernard (1972a) were low and negative, -0.08 and -0.04, respectively.

The published estimates of correlation between LWW and pig weaning weight were positive but varying from 0.12 reported by Omtvedt (1966) to moderate estimates of 0.36 and 0.39 reported by Fahmy and Bernard (1972a) and Argañosa et al. (1974/75), respectively.

Growth Performance Traits

Numerous studies on the performance traits of growing finishing pigs have been conducted in many countries, especially Europe and North America. Among these traits studied, average daily gain, feed conversion ratio and backfat thickness have been considered most important and reported abundantly in the literature.

Cop and Stelwagon (1971) reported that the average daily gain of 278 Dutch Landrace pigs from 139 litters was 883 g and that of 46 Large white pigs from 23 litters, 902 g. Dieguez and Castro (1974) reported that average daily gain of Large white, Duroc Jersey and Landrace boars were 759, 632 and 642 g, respectively as against 628, 681 and 595 g for barrows and gilts of the same breeds,

respectively. The average daily gain of Belgian, Swedish, German and British Landrace pigs weighing from 20 kg to 90 kg were 718, 713, 700 and 648 g, respectively (Poltrasky, 1978). The average daily gain of Duroc, Yorkshire and Landrace barrows reported by Wilson et al. (1979) were 757, 712 and 699 g, respectively. Thomeczek et al. (1979) reported that average daily gain for Duroc, Yorkshire and Landrace were 957, 462 and 953 g, respectively. Fabbri and Bergonzini (1981) reported that the average daily gain was 481 g in Large White as against 401 g in Durocs. The mean average daily gain in gilts, reported by Hutchens et al. (1981) was 0.69±0.003 kg. Costa et al. (1987) reported that the daily gain averaged 870.0± 3.52 g in 869 purebred pigs in Brazil. The average daily gain in 145 performance tested Landrace pigs recently reported in Korea by Jeon and Hong (1989) was 0.79±0.01 kg.

Hale and Southwell (1967) reported that feed per kilogram gain for Duroc and Hampshire pigs were 2.96 and 3.10, respectively. The feed efficiencies reported on 213 Duroc, 773 Yorkshire and 352 Landrace pigs by Bruner and Swiger (1968) were 2.91, 2.96 and 2.99, respectively. Thomeczek et al. (1979) reported that the feed conversion ratios of Landrace, Duroc and Yorkshire pigs were 2.69, 2.54 and 2.54, respectively. The feed conversion ratios determined at the official progeny testing stations in

Denmark for Landrace, Duroc, Landrace White, Hampshire and Pietrain pigs were 2.98, 2.71, 2.97, 2.95 and 3.08, respectively (Anonymous, 1979). Wilson and Johnson (1981) reported that the gain efficiency ratio (Gain/Feed) of Duroc, Hampshire and Yorkshire were 0.310, 0.307 and 0.321, respectively. Costa et al. (1987) reported that feed per kg gain in 869 pigs averaged 2.7±0.01 kg.

The backfat thickness of 225 Dutch Landrace and 225 Large White pigs reported by Valjneva (1969) were 4.00 and 3.36 cm, respectively. For Duroc, Hampshire, Large white, Duroc X Hampshire, Duroc X Large white and Hampshire X Large white gilts, the backfat thickness reported by Omtvedt et al. (1973) were 3.50, 2.95, 3.02, 3.10, 3.18 and 3.0 cm, respectively. Thomeczek et al. (1979) reported that backfat of Duroc, Yorkshire and Landrace were 2.18, 2.13 and 2.18 cm, respectively. In the study of Dieguez et al. (1979), for Large White, Duroc X Large White and Landrace X Landrace White gilts, backfat thickness at 100 kg bodyweight averaged 29.2, 27.9 and 29.4 mm, respectively. The mean backfat thickness in gilts, reported by Hutchens et al. (1981) was 2.52 ± 0.10 cm and that in 869 pigs, reported by Costa et al. (1987) was 2.5 ± 0.02 cm. The backfat thickness in test-station boars, on-farm boars and on-farm gilts, as reported by Van Diepen and Kennedy (1989) were 12.38±2.20, 13.20±2.57 and

14.47±2.75 mm, respectively, whereas that reported in Korea by Jeon and Hong (1989) averaged 18.64±0.30 mm.

Philippine Data

Important performance traits that are measurable on live pigs during on-farm performance testing have also been studied under the Philippine conditions by De Onon (1974), Abilay et al. (1976), Argañosa et al. (1979), Siagian (1984), Napoles (1985), Argañosa et al. (1986) and Lambio et al. (1986). Measurements of the traits reported in these studies were indicative of the performance levels of swine under particular conditions in their respective years in which they were reported.

De Onon (1974) reported the average daily gain of 20 to 90 kg Duroc, Yorkshire and Hampshire pigs to be 0.63, 0.62 and 0.54 kg, respectively. A grand mean ADG in boars of four different breeds and that in boars and gilts of three different breeds reported by Argañosa et al. (1979) were 826 and 808 g/day, respectively. Siagian (1984) and Argañosa et al. (1986) reported an overall average ADG of boars of three different breeds to be 763 ± 1.54 g/day as against 657±1.09 g/day in gilts of the same three breeds, reported by Siagian (1984). Napoles (1985) reported that ADG of gilts and boars belonging to purebred Pietrain,

Yorkshire, Duroc and crossbred Pietrain pigs were 647±3.57 and 691±3.97 g, respectively. Although Argañosa et al. (1979) reported higher ADG, other studies indicated that the level of this trait remained more or less the same through 1980's.

Argañosa et al. (1979) reported that a grand mean of feed conversion ratio (FCR) in boars of four different breeds and that in boars and gilts of three different breeds were 2.52 and 2.58, respectively. Siagian (1984) and Argañosa et al. (1986) reported the overall average FCR in boars of the three different breeds to be 2.45±0.004 as against 2.68±0.03 in gilts of the same three breeds reported by Siagian (1984). Purebred Pietrain, Yorkshire, Duroc and crossbred Pietrain gilts and boars had FCR values of 2.62±0.01 and 2.51±0.01, repectively (Napoles, 1985). Lambio et al. (1986) reported a combined average FCR of three different breeds to be 2.51±0.25. These studies showed that the level of FCR remained more or less constant through 1980's.

De onon (1974) reported that the Duroc had 2.66 cm of backfat thickness (BFT) , the Yorkshire , 2.74 cm and the Hampshire, 2.03 cm. A grand mean BFT in boars of four different breeds and that in boars and gilts of three different breeds were reported to be 2.71 and 2.75 cm, respectively (Argañosa et al., 1979). Siagian (1984) and

Argañosa et al. (1986) reported an overall average BFT in boars of three different breeds to be 2.47± 0.002 cm as against 2.45±0.002 cm in gilts of the same three breeds reported by Siagian (1984). Napoles (1985) reported that the average BFT in purebred Pietrain, Yorkshire, Duroc and crossbred Pietrain gilts and boars were 2.20±0.01 and 2.15±0.01 cm, respectively. A combined average BFT of three different breeds reported by Lambio et al. (1986) was 2.46±0.12 cm. These studies indicated that there was a trend of reduction in the level of BFT indicating slight improvement of the trait through the years of studies made.

Among the three most popular breeds, Landrace, Yorkshire and Duroc, the Yorkshire boars had the highest ADG and the best feed efficiency but also with thickest BFT compared to either the Landrace or Duroc boars, while the perfomance of the Duroc was better than the Landrace boars in ADG (Argañosa et al., 1986). Siagian (1984) reported that the boars apparently performed better than the gilts in terms of ADG and FCR irrespective of breeds. However, the Yorkshire and Duroc boars had thicker backfat than the gilts, while the Landrace boars had thinner backfat than the Landrace gilts.

Heritability Estimates

Numerous estimates of heritability of some performance traits particularly ADG, FCR and BFT are reported in the literature.

Average daily gain. The heritability estimates of average daily gain in weight of pigs (ADG) reported in Landrace bacon pigs, Large White pigs and average of eight other studies based on sire component of variance (Smith and Ross, 1965) were 0.41, 0.41 and 0.42, respectively. The heritability estimates based on regression of paternal offsprings and paternal halfsibs (Flock, 1970), regression of offspring on sire and regression of offspring on mid parent (Edwards and Omtvedt, 1971) and the estimates based on sire component of variance and average of literature reported by Young et al. (1978) and also the estimates of the trait in Large White bacon pigs based on sire component of variance reported by Curran (1973) were all within the range of 0.06-0.53 reported as the compiled range from the literature by Flock (1970). The range of estimates compiled from many sources around the world were 0.25 to 0.40 (Warwick and Legates, 1980) and 0.20 to 0.25 (Lasley, 1987). However, much higher estimates of heritability of the trait 0.69±0.18 and 0.54±0.14 based on parental halfsibs and maternal halfsibs, respectively were

reported by Hutchens et al. (1981). A comprehensive summary of heritability estimates for postweaning daily gain based on parental halfsibs correlations given in Table 1 (Hutchens and Hintz, 1981) shows extremely variable estimates reported by several authors.

Table 1. Summary of heritability estimates for postweaning daily gain, based on paternal halfsib correlation.

AUTHOR/S	BREED OR LINE	SEX	h^2 ESTIMATE
Johansson & Korkman, 1951.	Large White+ Swed. Landrace	mixed	0.26
Sutherland, 1958.	mixed	mixed	1.02
Brinks, 1960.	mixed	barrows	0.38
Jonsson & King, 1962.	Danish Landrace	mixed	0.45
Ward et al., 1964.	Minnesota synth.	mixed	0.62±0.10
Smith & Ross, 1965.	British Landrace	mixed	0.41
Biswas et al., 1966.	crossbred	mixed	0.77±0.37
Stanislaw, 1966.	purebreds	mixed	0.28±0.06
" "	crossbreds	mixed	0.39±0.10
Stockhousen & Boylan, 1966.	Managra	gilts	0.28±0.15
" "	Managra	barrow	0.28±0.18
	Managra	boar	0.58±0.40
Reutzel & Sumption, 1968.	Nebraska gene pool	gilts	0.34±0.17
Roy et al. 1968.	Managra	mixed	0.33±0.14
Isler, 1969.	mixed	mixed	0.35±0.07
Wong, 1969.	pure &crossbreds	mixed	0.47
Sider & Mojto, 1971.	-	-	0.98
Johnson, 1973.	crossbreds	gilts	0.37
Robinson & Berruecos, 1973.	-	barrows	1.11±0.27
Clarke et al., 1975.	L.White&Landrace	boars	1.02±0.29
Webb & King, 1976.	Swed. Landrace	mixed	0.26±0.
Young et al., 1976.	pure &crossbreds	mixed	1.03±0.21
Young et al., 1978.	Nebraska gene pool	gllts	0.3010.12
Hutchens, 1980.	mixed	gilts	0.69±0.18

Adapted from: Hutchens & Hintz, 1981.

The heritability estimates of ADG based on sire component of variance, reported more recently from Korea in Yorkshire, Landrace, Duroc and Hampshire were 0.203±0.085, 0.228±0.166, 0.389±0.204 and 0.067±0.141, respectively with the estimate averaged over the four breeds, 0.197 (Park et al., 1980).

In the Philippines, the heritability estimates of the trait in Yorkshire, Landrace, Duroc and those combined, based on sire component of variance were 0.33±0.06, 0.49±0.02, 0.06±0.06 and 0.49±0.09, respectively (Lambio et al., 1986). Recently, Lambio et al. (1990a) estimated heritability of the trait in Yorkshire, Landrace and combined breed at 0.21±0.11, 0.27±0.12 and 0.55±0.11, respectively.

Feed conversion ratio. Smith et al. (1962) reported that the heritability estimate of feed conversation ratio (FCR) in pigs, based on sire component of variance was 0.50. The estimates for Landrace bacon, Large White and average of eight other studies, based on sire component of variance were 0.48, 0.58 and 0.48, respectively (Smith et al., 1962 and Smith and Ross, 1965). The ranges of estimates compiled from many sources around the world were 0.30-0.40 (Warwick and Legates, 1980) and 0.25-0.30 (Lasley, 1987). The heritability estimates of feed per kg gain reported by Costa et al. (1987) was 0.43±0.16.

In the Philippines, Lambio et al. (1986) reported that the heritability estimates of the trait in Yorkshire, Landrace, Duroc and those combined, based on sire component of variance were 0.36±0.06, 0.16±0.6, 0.27±0.08 and 0.27±0.04, respectively. Recently, Lambio et al (1990a) estimated the heritability of the trait in Yorkshire, Landrace and combined breed to be -0.03±0.10, 0.15±0.12 and 0.15±0.08, respectively based on sire component of variance.

Backfat thickness. The heritability estimates of backfat thickness (BFT) in Landrace bacon, Large White and average of eight other studies, based on sire component of variance were 0.74, 0.66 and 0.54, respectively (Smith et al., 1962 and Smith and Ross, 1965). The estimates reported by several other workers, viz. Edwards and Omtvedt (1971) based on regression of offspring on parents; Kennedy et al. (1985) and Van Diepen and Kennedy (1989), based on sire component of variance; Berruecos et al. (1970), Hutchens et al. (1981) based on parental and maternal halfsibs; and Curran (1973), based on sire component of variance pooled within the herd were all within the range of estimates from 0.22 to 0.79 as reported to be compiled from the literature by Flock (1970). However, Young et al. (1978) reported a much

higher estimate of 0.89±0.13 based on sire component of variance.

The estimates based on regression of parent offsprings reported by Stockhausen and Boylan (1966) were generally lower ranging from 0.25 ± 0.15 in the case of dam barrow regression to 0.05±0.11 in the case of sire barrow regression. The estimates reported by Van Diepen and Kennedy (1989) based on sire component of variance for test-station boars, on-farm boars and on-farm gilts were 0.26, 0.52 and 0.44, respectively. The range of estimates for the trait compiled from several sources around the world by Craft (1958), Warwick and Legates (1980) and Lasley (1987) were 0.12-0.80, 0.40-0.60 and 0.40-0.50, respectively. A comprehensive summary of heritability estimates of live backfat based on paternal halfsib correlation, given in Table 2 (Hutchens and Hintz, 1981) shows extremely variable estimates reported by various authors. However, the trend is towards high values. This trend was also consistent with the heritability estimates of BFT, reported more recently by Park et al. (1990) from Korea, which were 0.286±0.102, 0.791±0.306, 0.626±0.265 and 0.356±0.214 in Yorkshire, Landrace, Duroc and Hampshire, respectively with the estimate averaged over the four breeds, 0.374.

In the Philippines, Lambio et al. (1986) estimated heritabilities of BFT in Yorkshire, Landrace, Duroc and those combined, based on sire component of variance to be 0.39±0.07, 0.55±0.11, 0.41±0.10 and 0.99±0.09, respectively. Recently, Lambio et al (1990a) reported the heritability estimates of the trait in Yorkshire, Landrace and combined breed to be 0.44±0.14, 0.46±0.14 and 0.51±0.09, respectively.

Table 2. Summary of heritability estimates of live backfat thickness based on paternal halfsib correlations.

AUTHOR/S	BREED/LINE	SEX	h^2 ESTIMATE
Sutherland,1958.	mixed	mixed	1.07
Brinks,1960.	mixed	barrows	1.08
Dillard et al,1962.	inbreds	mixed	0.09
Stanislaw, 1966.	purebreds	mixed	0.55±0.12
" "	crossbreds	mixed	0.47±0.13
Stockhausen & Boy-	Managra	gilts	0.53±0.68
lan,1966.	"	barrows	-0.07±0.22
" "	"	boars	0.56±0.44
Louca & Robison,	purebreds	boars	0.35±0.34
1967.	purebreds	barrows	0.14±0.15
" "	purebreds	gilts	0.33±0.18
" "	crossbreds	barrows	0.22±0.06
" "	crossbreds	gilts	0.09±0.05
Argañosa,1968.	mixed	mixed	0.62±0.19
Reutzel & Sumption,	Nebraska		
1968.	genepool	gilts	0.27±0.16
Wong, 1969.	pure+crossbreds	mixed	0.22
Clarke et al,1975.	Landrace+L.Whites	boars	0.86±0.28
Gajic et al,1976.	mixed	gilts	0.41
Webb & Jing,1976.	Swed.Landrace	mixed	0.63±0.13
Walters et al,1977	Large White	gilts	0.49
" "	Landrace	gilts	0.51
Young et al,1978.	Nebraska genepool	gilts	0.89±0.13
McPhee at al,1979.	L.white+Landrace	boars	0.47±0.11
Hutchens,1980.	mixed	gilts	0.15±0.14

Adapted from: Hutchens and Hintz (1981).

Correlations of Traits

Phenotypic and genetic correlations among only a few of the important performance traits, particularly daily gain, backfat thickness and feed conversion ratio are abundantly reported in the literature (Hutchens and Hintz, 1981 and Smith and Ross, 1965).

Phenotypic correlations. The weighted average of phenotypic correlation estimates between postweaning daily gain and live backfat thickness as summarized from literature by Hutchens and Hintz (1981) was 0.00. Nevertheless, the correlation estimates between these traits reported in the literature were variable ranging from negative estimates of -0.08 (Smith and Ross, 1965), -0.34 (Reutzel and Sumption, 1968) and -0.26 (Clarke et al., 1975), -0.07 (Young et al. 1978) to positive correlations ranging from 0.03 to 0.16; (Zoellener et al., 1963; Roy et al. 1968; Edwards and Omtvedt, 1971; Hetzer and Miller, 1972; Young et al. 1974; McPhee et al., 1979; Hutchens and Hintz, 1981 and Curran, 1973).

The phenotypic correlations between feed conversion ratio and daily gain were -0.66 in British Large White pigs (Smith et al., 1962) and -0.67 in British Landrace pigs (Smith and Ross, 1965).

The phenotypic correlations between feed conversion ratio and average backfat in British Large White pigs (Smith et al., 1962) and British Landrace pigs (Smith and Ross, 1965) were 0.19 and 0.44, respectively.

In the Philippines, phenotypic correlations among average daily gain (ADG), feed efficiency (FE) and backfat thickness (BFT) reported by Lambio et al. (1986) were significantly different from zero ($P<0.01$). They reported a high and positive phenotypic correlation of 0.53 between ADG and FE, while they found low positive correlation, 0.14 between ADG and BFT and low negative correlation, -0.03 between FCR and BFT. On the other hand, recently a moderate negative correlation (r_p = -0.34) between ADG and FCR was found by Lambio et al. (1990a) in combined Yorkshire and Landrace population in which low positive phenotypic correlations (r_p = 0.11 and 0.01) between ADG and BFT; and FCR and BFT, respectively were also reported.

Genetic correlations. The weighted average of genetic correlation between postweaning daily gain and live backfat adapted from 17 studies was -0.05 (Hutchens and Hintz, 1981). Nevertheless, the correlation estimates reported in the literature were highly variable ranging from negative correlations falling between -0.7 and -0.98 (Smith and Ross, 1965; Stockhausen and Boylan, 1966; Reutzel and Sumption, 1968; Flock, 1970; Edwards and

Omtvedt, 1971; Hetzer and Miller, 1972; Clarke et al., 1975 and Young et al., 1978) to positive correlations falling between 0.09 and 0.70 (Zoellener et al. 1963; Hetzer and Miller, 1972; Robison and Berruecos, 1973; McPhee et al., 1979 and Hutchens et al., 1981) depending upon the estimation methods, breeds, sex and number of animals used. The genetic correlations of gain per day with fat depth at shoulder and loin were 0.16 and 0.25, respectively (Curran, 1973).

In the Philippines, genetic correlation between the performance traits, ADG and FE was relatively high and negative (r_g = 0.52) and the genetic correlation of ADG with BFT was moderate positive (r_g = 0.24), while that between FE and BFT was found to be 0.00 as reported by Lambio et al (1986). According to recent study (Lambio et al, 1990a), the genetic correlations between ADG and FCR, ADG and BFT and FCR and BFT were -0.99, -0.24 and -0.27, respectively in a combined Yorkshire and Landrace population in the Philippines.

Selection Index

Selection for an index score which gives proper weight to each of the traits is more efficient than selection for one trait at a time or for several traits with an independent culling level for each trait (Hazel

and Lush, 1942). Such an index designed for the selection of plant lines was first developed by Smith (1936). Selection index as the criterion of selection for multiple traits was first developed for animal applications by Hazel (1943).

Hazel (1943) illustrated three selection indices for young boars and gilts from data taken on the Iowa Station swine herd. According to him, the constants that must be known in order to solve the simultaneous equations in a multiple correlation method of constructing selection indices having maximum accuracy, are relative economic values for the different traits, heritability of each trait, standard deviation for each trait and phenotypic and genetic correlations between each pair of traits. He also emphasized that an index constructed from data taken on a herd in one locality may not be widely applicable due to variations in relative economic values for traits with the particular locality or nature of enterprise, in the genetic constitution of herd under distinctly non-random mating systems, in management practices causing varying standard deviation in different herds.

Karam et al. (1953) suggested four indices for selecting lambs for replacements in farm flocks essentially on the basis of the genetic principles outlined by Hazel (1943) but with provision of easier

modification of the index with change in the relative economic values of the traits, as suggested by Henderson (1951, as cited by Karam et al., 1953). The genetic values of the traits included in these indices were weighted by their respective relative economic values per se and in relation to other traits which contribute to profit in the enterprise. They also computed the relative economic value assigned to each trait as the relative effect which this trait was assumed to have on profit when it varied one unit in a flock of a certain size.

Bernard et al. (1954) constructed indices for selecting young pigs raised under farm conditions. The relative economic value of the trait was determined by the procedure given by Karam et al. (1953) and was combined with phenotypic and genotypic variances and covariances to construct a selection index in the way outlined by Hazel (1943) with a modification suggested by Henderson (1951) as cited by Bernard et al. (1954).

The concept of a general selection index which had wider applicability was introduced by Hanson and Johnson (1957). They raised a pertinent question whether a selection index determined from a source of data can be used as a general index for a breeding program considering the sampling errors expected for the estimated weights of the index and the errors involved in the estimation of

genetic X environment interactions. They presented criterion for the determination of a general selection index obtained by pooling information from two or more segregating populations. The criterion was that phenotypic weights be so selected that the average genetic advance is maximum.

Robison et al. (1960) developed selection indices utilizing the body measurements with measures of production traits in which relative economic values of a unit change in individual pig weight at 154 days of age, percent lean cuts and litter size at 154 days, in terms of net income, were estimated.

Minkema et al. (1964) constructed a fairly simple selection index in which each trait was weighted by the product of its economic value and its heritability. Genetic correlations among the traits were not taken into consideration owing to the lack of sufficient information. Accurate economic value of a trait was estimated for Dutch conditions at the moment of selection.

Swiger et al. (1979) derived selection indices for postweaning growth, carcass and feed consumption traits on "a pen of two" basis and suggested that testing two littermate boars in a pen had a 6% advantage in predicting net merit compared to testing a single boar.

McPhee et al. (1979) constructed selection indices using four traits, daily weight gain, feed conversion ratio, daily feed intake and subcutaneous fat depth. The economic values computed for unit change in these selection traits were 2030c, -910c, -44c and zero, respectively.

Melton et al. (1979) developed a procedure to estimate economic values for use in selection indices based on the average values of the traits, the available inputs and their prices, output prices and specified production function.

Buchanan and Luce (1985) evaluated the degree to which various measures of performance traits contributed to the selling price of the tested boars. The values obtained from the partial regression of selling price on each trait gave the average change in selling price per unit change in the performance trait while holding all other variables constant.

In a simplified method of obtaining selection index, "b" weights were derived by Slanger and Ogunlola (1983) for a single trait selection in the situation where the covariances among the averages of the records of the genetic groups were equal and the covariances between the averages of the records of the genetic groups and the true value predicted were equal.

Many more selection indices have been developed by several workers for use in a particular herd or group of herds under more or less constant environment. However, it is generally assumed that an index developed for use under one environment may not be effective when used under other conditions (Christian, 1957). Chyr (1980) analysed the risks of adopting the United States swine selection index in Taiwan and built four indices by considering Taiwanese local situation of swine production. A boar selection index recommended by his study was significantly different from the U.S. index, as the relative economic values of the traits ADG, FE and BFT were different.

In the Philippines, a selection index developed in Iowa Testing Station in the United States is being currently used for performance testing (Argañosa et al., 1986). Pham (1972) attempted to construct a locally suited selection index for sow productivity, but it was not recommended for practical use due to the nature of data used in its construction. Recently, Lambio et al (1990b) attempted to construct selection indices for different trait combinations among ADG, FCR and BFT in commercial pigs but they assumed relative economic weights of traits to be equal i.e. one to one.

MATERIALS AND METHODS

Study I: Litter Performance Traits

Source of Experimental Data

A swine herd comprising of three genotypes, namely Landrace, Yorkshire and their crosses, raised at the Government owned Livestock Development Farm, Lampatan, Pokhara in Nepal was the source of the experimental data for the present study on litter performance traits. The herd developed from the grand parent stock imported from Singapore in 1979 and the previous stock at the farm, was maintained with the main objective of producing piglets for dispersal to the small scale breeder farmers for the improvement of swine stock in the country.

Data were obtained from the records of a total of 1387 piglets born in 147 litters farrowed by a total of 59 sows and sired by seven boars between May 1983 and June 1988. Inbreeding was avoided in the herd by disallowing the matings between direct relatives and hence the effect of inbreeding was considered negligible in the present study. All animals in the herd were given similar management conditions irrespective of genotype groups and were fed with standard rations mixed at Government owned Hetauda Feed Plant. Data on six litter performance traits, namely litter size at birth (LSB) measured as the total

number of pigs born, litter birth weight (LBW, kg), litter size at weaning (LSW) measured as the the total number of pigs weaned, percentage weaning of total pigs born (PWT, %), litter weaning weight (LWW, kg) and average pig weaning weight (AWW, kg) were collected for the present study from the farm records. Although weaning of piglets was generally practiced around 45 days of their age, weaning ages of the piglets under the present study spanned from 30 to 60 days due to practical problems of scheduling dispersal of weanlings to different districts of the country. The data on litter weaning weight affected by the variations in weaning age were adjusted accordingly to litter weights at 42-day basis using simple correction factors similar to those suggested by Lasley (1987).

Out of the total records of 147 litters included in the study, records of litter size at birth and litter birth weight were available for all litters, while records of litter size at weaning and litter weaning weight were available only for 140 and 85 litters, respectively. Also, percentage weaning of total pigs born and average weaning weight were computed for 140 and 85 litters, respectively. Further classification of litter records according to different categories namely, sire, dams, litters and their breeds is presented in Appendix Table 1.

Statistical Procedures

Experimental design. All records of litters from three genotype groups were pooled and laid on a hierarchical classification in which each sire was mated to several dams and each dam had produced more than one progeny litters. Only those records which were fitted on this design were included in the study. Measurements of traits in those progeny litters were expected to be non-orthogonal with effects due to disproportionate and unequal subclass numbers.

The most important class factors that could possibly affect the variability of each of litter performance traits under the farm conditions were breed (genotype groups), parity of dams, year-season of farrowing, sire and dam effects. Preliminary investigation of data revealed that no fixed effect was significant in litter size at birth, while only fixed effect of genotype was significant ($P<0.05$) in other traits. However, due to the limited data-set, the fixed effect of genotype was not considered and the pooled data was used, instead. The effects of sires and dams were considered random. Hence, a random model of the "nested" classification for each litter performance trait was assumed as follows:

$$Y_{ijk} = \mu + S_i + D_{ij} + \epsilon_{ijk},$$

Where:

Y_{ijk} = the phenotypic measurement or record of the trait in the kth litter of jth dam within ith sire;

μ = general mean of measurement or record of the trait;

S_i = random effect of the ith sire, with i=1,2..p, where p is the number of sires;

D_{ij} = random effects of jth dam within the ith sire with j=1,2..q, where q is the number of dams;

ϵ_{ijk} = random error unique to each litter.

The assumptions made in the above model for the analysis of variance were that :a) the data-set followed normal distribution: b) all errors were normally and independently distributed about the mean of zero and the error variance i.e. NID (0, σ^2) (Eisenhart, 1947 and Argañosa, 1968).

The analysis of variance was conducted for each trait by employing the least-square technique of fitting constants (Harvey, 1960) because of the disproportionate and unequal subclass numbers in the data-set.

Estimation of heritabilities. The term "heritability", restricted to mean the heritability in the narrow sense as defined by Falconer (1981) could be expressed as:

$$h^2 = \frac{\sigma^2_A}{\sigma^2_P},$$

where:

h^2, σ^2_A and σ^2_P are the heritability estimate, the additive genetic variance and the total phenotypic variance, respectively, of the trait.

In this study, heritabilities of the litter performance traits considered were estimated based on the sire component of variance.

The assumptions made in estimating heritability from components of variance were: (i) the sire component of variance was one-fourth of the additive genetic effects, (ii) dominance and epistatic effects were non-exitent, (iii) inbreeding was zero. The analysis of variance of each trait for estimating the components of variance was as illustrated in table 3.

Table 3. Analysis of variance for nested classification of litter performance traits (Illustration).

SOURCE OF VARIATION	DEGREES OF FREEDOM	MEAN SQUARES	EXPECTED MEAN SQUARES
Between sires	S-1	MSs	$\sigma^2_e + k_2 \sigma^2_d + k_3 \sigma^2_s$
Between dams within sires	D-S	MSd	$\sigma^2_e + k_1 \sigma^2_d$
Between litters within dams	N-D	MSe	σ^2_e

Notations:

S = number of sires; D = number of dams; N = total number of observations; k_1, k_2, k_3 = coefficients that aproximate the average number of observations in each subgroup (Becker, 1975); MSs, MSd and MSe were the mean squares of sire, dam and progeny litters, respectively; σ^2_e , σ^2_d, σ^2_s= random error, dam and sire components of variance, respectively.

From the ANOVA table as illustrated above the components of variance was computed using the equations (Becker, 1975) :

$$\sigma^2_e = MSe \ ;$$

$$\sigma^2_d = \frac{MSd - MSe}{k_1} \ ; \qquad \sigma^2_s = \frac{MSs - (\sigma^2_e - k_2 \sigma^2_d)}{k_3}$$

The heritability estimate of each of the litter performance traits was then computed using the equation (Becker, 1975):

$$h^2 = \frac{4\,\sigma^2_s}{\sigma^2_s + \sigma^2_d + \sigma^2_e};$$

which represented the estimate based on paternal half sib correlation.

The sampling error or standard error of the heritability estimate (S.E.of h^2) of the trait was computed using the method described by Dickerson (1960) as follows:

$$\text{S.E. of } h^2 = \frac{\sqrt{4\left[\frac{2}{(k s)^2}\left[\frac{MSs^2}{S-1} + \frac{MSd^2}{D-S}\right]\right]}}{\sigma^2_s + \sigma^2_d + \sigma^2_e}$$

Correlations of traits. In this study, phenotypic and genetic correlations between all pair combinations of the litter performance traits were obtained by methods of analyses of variance and covariance similar to those used for obtaining heritability (Becker, 1975). A covariance analysis similar to the analysis of variance, for

obtaining components of covariance was conducted in the the two way "nested" classification, as illustrated in table 4.

Table 4. Analysis of covariance for nested classification of litter performance traits (Illustration).

SOURCE OF VARIATION	DEGREE OF FREEDOM	MEAN CROSS-PRODUCTS	EXPECTED MEAN CROSSPRODUCTS
Between Sires	S-1	MCPs	$COV_e + k_2 COV_d + k_3 COV_s$
Between Dams within Sires	D-S	MCPd	$COV_e + k_1 COV_d$
Between Litters within Dams	N-D	MCPe	COV_e

The sire, dam and error components of variance, σ^2_s, σ^2_d and σ^2_e, respectively for each of paired traits, say a and b, were obtained from the analysis of variance as illustrated above. The sire, dam and error components of covariance, COV_s, COV_d and COV_e respectively between the two traits were solved as follows:

$$COV_e = MCPe ,$$

$$COV_d = \frac{MCPd - MCPe}{k_1} ,$$

$$COV_s = \frac{MCPs - (COV_e + k_2 COV_d)}{k_3} .$$

The phenotypic correlation (r_p) between the traits, a and b, was then estimated using the equation (Becker, 1975):

$$r_p = \frac{COV_a + COV_d + COV_e}{\sqrt{\{\sigma^2_{s(a)}+\sigma^2_{d(a)}+\sigma^2_{e(a)}\}\{\sigma^2_{s(b)}+\sigma^2_{d(b)}+\sigma^2_{e(b)}\}}}$$

The genetic correlation (r_g) between two traits was estimated using the equation based on sire components of variance and covariance (Becker, 1975) as follows:

$$r_g = \frac{COV_a}{\sqrt{\sigma^2_{s(a)} + \sigma^2_{s(b)}}} .$$

The standard error of genetic correlation (S.E. of r_g) of each pair of traits, say a and b, was computed using the equation given by Robertson (1959):

$$\text{S.E. of } r_g = (1 - r_g^2)\sqrt{\frac{\text{S.E. of } h^2_{(a)} \cdot \text{S.E. of } h^2_{(b)}}{2\, h^2_{(a)} \cdot h^2_{(b)}}},$$

where:

r_g^2= genetic correlation coefficient squared,

S.E.s of $h^2_{(a)}$, $h^2_{(b)}$= the standard errors of heritability

estimates of the traits, a and b respectively; $h^2_{(a)}$, $h^2_{(b)}$ = the heritability estimates of the traits, a and b, respectively.

Economic values of traits. Economic values of litter performance traits were estimated using a procedure developed by Melton et al. (1979) with some modifications in assumptions of production conditions. Assuming the farm concerned as a producer or firm in economic terms, production of weanlings from a litter was achieved by combining a number of inputs, including the capacity of the litters and producer supplied resources. However due to lack of sufficient information, producer- supplied resources were considered constant for all litters at Rupees 1797.70, the average cost of litter harvest as reported by Shrestha et al. (1988). The technical relationship between dispersal sales of weanlings (outputs) and resources (inputs) were expressed by a production function such that inputs were partitioned into two categories-those inherently embodied to the litters, i.e. litter traits and those exogenously supplied by the firm as expressed by cost of litter production (COP). Then the litter entity production function, i.e. the number of weanlings produced or litter size at weaning (LSW),

$$LSW = f \text{ (litter traits)}$$

was represented by a second-order Taylor-series expansion of an unknown functional form (Heady and Dillon, 1961) and was expressed as:

$$Y = \tau + \Sigma\, \tau i.Xi + \Sigma\, \tau i.(Xi)^2 + \Sigma\, \tau i.Xi.Xj,$$

with the corresponding profit function,

$$\pi = P_y\,(Y) - \Sigma\, Pi.(Xi) - COP.,$$

where:

P_y = the price per unit of output; Y = the units of output, P_i = the price per unit of ith input, Xi = units of ith input used, COP = the cost of production of weanlings (output) and τ's = the intercept and regression coefficients of input variables. However, if the regression of variables in the Taylor-series expansion on the output was found to be non significant, the corresponding terms were removed from the series by backward elimination procedure to derive a final model. As it was assumed that the firm wished to maximize profits, the partial derivative of the profit function with respect to each variable was equated to zero in order to maximize the function mathematically and the resulting system of first-order conditions for optimal levels of variables were simultaneously solved. This procedure yielded simultaneous relations expressed as:

$$\frac{\delta\pi}{\delta(Xi)} = P_y \frac{\delta(Y)}{\delta(Xi)} - Pi = 0$$

or, $$Pi = Py \frac{\delta(Y)}{\delta(Xi)}, \quad i = 1,.....m$$

$$Pj = Py \frac{\delta(Y)}{\delta(Xj)}, \quad j = m+1,....n.$$

The economic value of each trait was determined by substituting average values of all traits considered, the available producer supplied inputs and their prices, the price of the final product (output) in the above simultaneous relationships for solving them.

Selection index. Among the litter performance traits studied, selection indices for appropriate combinations of traits selected on the basis of their genetic and phenotypic parameters were constructed. The technique involved was essentially based on the standard theory of selection index described by Hazel (1943) and subsequently modified by Karam et al. (1953), Bernard et al. (1954), Hogsett and Nordskog (1958) and Robison et al. (1960). The step-wise computation of the index was made using the procedure described by Becker (1975) as follows:

1. The genetic variance (Var_A), phenotypic variance (Var_P), genetic covariance (Cov_A) and phenotypic covariance (Cov_P) among the traits were obtained from the

hierarchial type of analyses of variance and covariance used previously in the estimation of the genetic and phenotypic parameters. It was assumed that the total genetic variance and covariance were adequately represented by the additive genetic variance and covariance.

2. The relative economic weights (a_1, a_2, a_3) for say, three traits were obtained from the economic values of traits determined previously from the average values of the traits based on the production function.

3. The aggregate genotypic value (T) of the index was then represented as :

$$T = a_1.G_1 + a_2.G_2 + a_3.G_3,$$

where, a's refer to the relative economic weights and G's are the genotypic values of the three traits, respectively.

4. The normal simultaneous equations to be solved to obtain the coefficients for the corresponding traits considered in the construction of the selection index were as given below:

$$\begin{aligned} &VarP(x_1)\ b1 + CovP(x_1x_2)\ b2 + CovP(x_1x_3)\ b3 \\ &\quad = VarA(x_1)\ a1 + CovA(x_1x_2)\ a2 + CovA(x_1x_3)\ a3 \end{aligned}$$

$$\begin{aligned} &CovP(x_2x_1)\ b1 + VarP(x_2)\ b2 + CovP(x_2x_3)\ b3 \\ &\quad = CovA(x_2x_1)\ a1 + VarA(x_2)\ a2 + CovA(x_2x_3)\ a3 \end{aligned}$$

$$\begin{aligned} &CovP(x_3x_1)\ b1 + CovP(x_3x_2)\ b2 + VarP(x_3)\ b3 \\ &\quad = CovA(x_3x_1)\ a1 + CovA(x_3x_2)\ a2 + VarA(x_3)\ a3 \end{aligned}$$

where:

$VarP_{(x_i)}$ = phenotypic variance of ith trait,

$VarA_{(x_i)}$ = additive genetic variance of the ith trait,

$CovP_{(x_i x_j)}$ = phenotypic covariance between ith and jth traits,

$CovA_{(x_i x_j)}$ = additive genetic covariance between ith and jth traits, where i,j = 1,2,3; and

ai = relative economic weight of the ith trait,

bi = partial regression coefficient of ith trait.

5. These normal equations were represented in matrix notations:

$$P\,\underline{b} = G\,\underline{a}$$

where,

P = the variance-covariance matrix of phenotypic values,

G = the variance-covariance matrix of genotypic values,

$\underline{b}$ = the vector of partial regression coefficients of the X's in the index and

$\underline{a}$ = the vector of relative economic weights.

6. Inverting the phenotypic matrix, the b's were obtained as:

$$\underline{b} = P^{-1}\,G\,\underline{a}$$

7. The selection index (I) was then, derived as:

$$I = [\ b1\ b2\ b3\ ] \begin{vmatrix} X1 \\ X2 \\ X3 \end{vmatrix} ,$$

or,

$$I = b1\ X1 + b2\ X2 + b3\ X3 ,$$

where X's are the measurements of three traits in the litter.

8. Finally, the relative efficiency of the index was determined as the correlation of the index and the aggregate genotype (T), expressed as:

$$r_{IT} = \frac{\sigma_{IT}}{\sigma_I . \sigma_T} = \frac{\sigma_I}{\sigma_T} ,$$

where: the variance of the index,

$$(\sigma_I)^2 = \underline{b}^T.P.\underline{b},$$

the variance of the aggregate genotype,

$$(\sigma_T)^2 = \underline{a}^T.G.\underline{a} ,$$ and

the covariance of index and aggregate genotype,

$$\sigma_{IT} = \underline{b}^T.G.\underline{a} = \underline{b}^T.P.\underline{b}$$ (Cunningham, 1969a.)

Study-II: Growth Performance Traits

Management of Experimental Animals

An on-farm performance testing of Nieuw Dalland (hybrid) pigs was conducted at the International Training Center on Pig Husbandry (ITCPH) Farm at Lipa City, Batangas Province of the Philippines. Forty two barrows and twenty one gilts that had entered 10 selected fattening pens between November and December, 1990 were considered for this study. Each of the pigs was dewormed with Ivomec@ and vaccinated against Hog Cholera when they were in nursery care before entering the fattening pens. At the time of transferring them from nursery pens to the fattening pens, pigs were individually weighed and a group of seven growing pigs were assigned to each fattening pen. Only the pigs that were more than 20 kgs in initial weights and those which weighed more than 70 kgs on the cut-off date of the testing, March 2, 1991 were finally considered for the study.

Pigs were fed with standard rations produced by a cooperative feed miller which was the regular supplier of feeds to the ITCPH Farm. Pigs were given Hog grower ration when their weights were between 20 and 60 kgs and were given Hog finisher ration thereafter until market weights.

@ Ivermectin Trademark of Merck & Co., Inc., USA.

Pigs were under the group feeding system within a pen and were given two-time restricted feeding at 8.00 A.M. and 3.00 P.M. It was assumed throughout the testing period that all pigs in any particular pen received equal amounts of feed in a feeding session, due to difficulties in determining the exact amount of feed consumed by a pig under group feeding system. Hogs were generally marketed by ITPCH Farm when their weights were around 80 kgs and in all cases above 70 kgs. However, the exact final weights of the hogs were dependent on scheduling their sales in batches. Hence, For the purpose of this study, only pigs marketed before the cut-off date of the testing or weighed above 70 kgs of final weight on the cut-off date were included.

Experimental Data

Measurements of performance traits and relevant information on cost of production of fattening pigs constituted the experimental data. The following experimental data were gathered in this study:

1. The initial age of each pig at the time of placing them into the fattening pen was considered as the age at start.

2. The weight of pig at the initial age was considered as the initial weight.

3. The duration of time from the first day the pig was placed into the fattening pen up to the date on which it was sold or the cut-off date whichever was earlier, was considered as the number of days the pig was on test.

4. The weight of the pig at the end of its testing was considered as the final weight.

5. The difference between final weight and initial weight of the pig tested was considered as total gain in weight.

6. Average daily gain (ADG, kg) day was measured as the ratio between the total gain in weight of pig and the number of days on test.

7. Feed Conversion Ratio (FCR) was measured as the ratio between total amount of feed consumed by a pig and total gain in weight made by the pig during the testing period.

8. Backfat Thickness (BFT, cm) was measured as the average of three measurements of backfat thickness of pig taken at three standard sites by using Renco Leanmeter, a digital backfat indicator, at the end of test.

9. Feed cost involved in the production of the marketable pig was computed on the basis of the amount of feed consumed by a pig during the testing period at an average price.

10. Initial price of the pig was computed on the basis of initial weight of the pig at prevailing prices.

11. Interest on land use, depreciation cost of housing and equipment, interest on capital investment, cost of repairs and maintenance, cost of labor, veterinary expenses and interest on working capital were computed for each pig tested on the basis of assumptions of technical coefficients presented in Appendix Table 6.

12. The expenses on electricity and water consumption were determined from the actual observations on the cost of electric wattage and volume of water utilized for hogs daily through their on-farm testing at the prevailing average prices (Appendix Table 6).

13. All prices assumed for this study were averages of the prices prevailing in 1990 and were gathered from various sources cited in Appendix Table 6.

14. Finally, the cost of producing each of market hogs tested was computed using the steps suggested by Amir and Knipscheer (1989) for the generalized cost of production (COP).

Statistical Procedures

Phenotypic parameters. Means and standard errors of the traits, phenotypic correlations, variances and covariances of the traits were estimated from the data-set

obtained from the on-farm performance testing of pigs in the present study using least square analysis and Pearson's correlation procedures.

Genetic parameters. Genetic parameters particularly estimates of heritabilities and genetic correlations of ADG, FCR and BFT required for this study to derive genetic variances and covariances of the traits were not estimated due to the paucity of appropriate data required for their estimation. However, the estimates of these parameters estimated by Lambio et al. (1986) from sizable number of on-farm performance tested pigs in the Philippines were considered reliable and were used in this study. Genetic variances of the traits were computed with the assumption that the additive genetic variance represented the total genetic variance, using the following formula (Cunningham, 1969b):

$$VarA_{(x_i)} = h^2_{(x_i)} . VarP_{(x_i)},$$

where:

$VarA_{(x_i)}$ = genetic variance of the ith trait;

$h^2_{(x_i)}$ = heritability estimate of the ith trait; and

$VarP_{(x_i)}$ = phenotypic variance of the ith trait.

Similarlly, genetic covariances among traits were computed using the following formula (Cunningham, 1969b):

$$CovA(x_i x_j) = r_g . \sqrt{VarA(x_i) . VarA(x_j)}$$

where:

$CovA(x_i x_j)$= genetic covariance between ith and jth traits

$VarA(x_i)$= genetic variance of ith trait;

$VarA(x_j)$= genetic variance of jth trait; and

r_g= genetic correlation between the two traits.

Economic values of traits. Economic values of ADG, FCR and BFT for use in selection indices were estimated using a procedure developed by Melton et al. (1979). Assuming ITPCH Farm as a producer or firm in economic terms, production of marketable hogs was achieved by combining a number of inputs, including the capacity of the animals and producer supplied resources (inputs) such as feed, labor and capital, according to certain biological and technical rules. The technical relationship between products (outputs) and resources (inputs) were expressed by a production function such that inputs were partitioned into two categories those inherently embodied in the animal, namely ADG, FCR and BFT and those exogenously supplied by the firm as expressed by its cost of production (COP). Then, the animal entity production function defined as the final weight (FWT) of marketable pig,

FWT= f (ADG, FCR, BFT, COP),

was represented by a second-order Taylor-series expansion of an unknown functional form (Heady and Dillon, 1961) and was expressed as:

$$FWT = \tau + \tau 1(ADG) + \tau 2(FCR) + \tau 3(BFT) + \tau 4(COP) + \tau 5(ADG)^2 + \tau 6(FCR)^2 + \tau 7(BFT)^2 + \tau 8(COP)^2 + \tau 9(AGD.FCR) + \tau 10(ADG.BFT) + \tau 11(ADG.COP) + \tau 12(FCR.BFT) + \tau 13(FCR.COP) + \tau 14(BFT.COP);$$

with the corresponding profit function,

$$\pi = P_y (FWT) - \Sigma P_i.(Xi) - COP,$$

where:

P_y = the price per kg of FWT; P_i = the price per unit of the ith input; Xi = the unit of ith input such as ADG, FCR or BFT; COP = the cost of production of one marketable hog (output); and τ's = the intercept and regression coefficients of input variables. However, if any of regression coefficients of input variables in the Taylor-series expansion on the output was found to be non-significant, the corresponding term was removed from the series and appropriate regression analysis was conducted to derive a final fitting model. As it was assumed that the firm wished to maximize profits, the partial derivative of the profit function with respect to each variable was equated to zero in order to maximize the function mathematically and resulting system of first

order conditions for optimum levels of variables were simultaneously solved. The simultaneous relations yielded by this procedure were expressed as:

$$\frac{\delta \pi}{\delta(Xi)} = P_y \frac{\delta(FWT)}{\delta(Xi)} - Pi = 0$$

$$\text{or, } P_{ADG} = P_y \frac{\delta(FWT)}{\delta(ADG)},$$

$$P_{FCR} = P_y \frac{\delta(FWT)}{\delta(FCR)} \text{ and}$$

$$P_{BFT} = P_y \frac{\delta(FWT)}{\delta(BFT)}.$$

The economic values of each trait was determined by substituting average values of all traits considered, the available producer supplied inputs and their average prices, the price of the final product (FWT) in the above simultaneous relationships.

Selection index. The selection index considering ADG, FCR and BFT was constructed using basically the same technique employed previously for litter performance traits.

Analyses of Data

Analyses of all data were carried out in IBM compatible microcomputers using Lotus 1-2-3, Statgraphics, Statistical Analysis System (SAS Institute, 1985) and Mathcad softwares.

RESULTS AND DISCUSSION

Study I: Litter Performance Traits

Means and Standard Errors

The least square means and standard errors of six litter performance traits in three genotypes pooled for this study are presented in Table 5. The least square mean of litter size at birth (LSB) in the herd in Nepal was 9.435±0.272 and was comparable to the first litter record averages of 9.48 and 9.2 reported by Silvinskaya (1974) and Jancic et al. (1980a), respectively. The figure was also fairly close to the averages of 9.66, 9.27 and 9.20±0.26 reported in litters of 174 sows (Jancic et al., 1980b), in 687 Duroc litters (Alves et al., 1989) and in a herd in the Philippines (Argañosa et al., 1990a), respectively, while it was larger than the averages reported in Landrace, Landrace x large White and Large White (Deo et al., 1980) and Large White litters (Gupta et al., 1983b) in India. Nevertheless, the figure in this study could be generally considered lower than that was reported by other studies in many herds of purebreds and crossbreds (Jancic et al., 1982a; Lambio et al. 1986; Rhee et al., 1987; Alves et al., 1989 and Argañosa et al., 1990b) and was much lower than LSB in Taihu breed with 16 pigs born in a litter (Wu and Zhang, 1983 and Zhang,

1983). The least square mean of litter birth weight in the three genotypes pooled for the study was 10.604±0.393 kg and was generally lower than that reported by several authors (Vangelov, 1970; Argañosa et al., 1974/75; and Alves et al., 1989) in the range from 11.5 to 16.00 kg. but was slightly higher than those, 9.40 and 9.26 kg reported by Fahmy and Bernard (1972a), respectively.

The least square mean of litter size at weaning (LSW) in three genotypes pooled in Nepal was 6.907±0.328 which was consistent with the figures, 7.09 and 6.82±0.10 reported by Fahmy and Bernard (1972a and 1972b), but was generally lower than the other figures reported in the literature during the contemporary periods (Gupta et al., 1983b; Park et al., 1987 and Rhee et al., 1989). LSW in the present study was also lower than that in a herd in the Philippines (Argañosa et al., 1990a) having slightly lower litter size at birth than in the present study.

The least square mean of percentage weaning of total pigs born (PWT) in the present study was 75.296±2.838 which was slightly lower than the percentage figure of 79.5±0.77 and 82.06±2.27 and 79.52±1.83 reported in the Philippines by Argañosa et al. (1974/75), Argañosa et al. (1990a and 1990b), respectively, even though the latter two were reported for the corresponding contemporary period of this study between 1983 and 1988.

Table 5. Least square means (LSM) and standard errors (SE) of litter performance traits in the swine herd in Nepal.

TRAITS	n	LSM	± S.E.
Litter size at birth (LSB)	147	9.435	0.272
Litter birth weight (LBW, kg)	147	10.604	0.393
Litter size at weaning (LSW)	140	6.907	0.328
Percentage of weaning based on total number of pigs born (PWT, %)	140	75.296	2.838
Litter weaning weight on 42-day basis (LWW, kg)	85	47.026	5.055
Average weaning weight of pig on 42-day basis (AWW, kg)	85	6.626	0.347

n = number of litters studied

The least square mean of litter weaning weight (LWW) adjusted to 42 days in three genotypes pooled was 44.026±5.055 kg which can be considered generally less than weights of litters at weaning reported in the literature, as the least square mean of LWW at 35 days reported by Argañosa et al. (1974/75) was 48.09±0.71 kg, that at 30 days reported by Park et al. (1987) was 70.7±0.06 kg and also the weights of Landrace and Large White litters at 21 days reported by Alves (1989) were 46.79±0.32 and 48.03±0.43 kg, respectively.

The average pig weaning weight adjusted to 42 days in the litters studied was 6.626±0.347 kg, which was

nearly the same as the average weaning weight of the pigs, 6.27 kg at 35 days reported by Argañosa et al. (1974/75) and was considerably lower than the weights reported in the most other literature (Omtvedt et al., 1966; Strang, 1970 and Fahmy and Bernard, 1972a).

The standard errors of the measurements of six traits studied were relatively high mainly due to sampling errors arising from a limited data set considered for the study. Hence, the trends of trait measurements could be considered within limits of those in the literature, despite means of the traits in this study were slightly lower than most estimates reported for the contemporary periods.

Heritability Estimates

In the estimation of genetic parameters such as heritabilities, the litter performance traits were considered as the traits of the gilts that were born in the litters studied in the manner of the studies made by Argañosa et al. (1974/75) on sow productivity and Young et al. (1978) on the prebreeding traits of gilts rather than as the traits of the dams of the litters as reported in most other studies. The heritability was estimated for each trait on the basis of only sire component of variance. The dam component of variance was largely biased

and inaccurate due to maternal effects on the litter performance and also sampling errors arising from the small data-set used for study and hence was not considered for estimation of genetic parameters.

Heritability estimates of six litter performance traits studied in three genotypes pooled and their corresponding standard errors are presented in Table 6. Despite small data-set used in the present study, the heritability of litter size at birth was surprisingly the same as the literature average reported by Haley et al. (1988) in an extensive review, except for the slightly higher standard error in the present study. The estimate was either consistent or very close to most other estimates which were in the range of practically zero (Polyanichko, 1973 and Wu and Zhang, 1983) to below 0.20 (Vangelov, 1970; Kryatov, 1972; Walker et al., 1973; Gajic, 1974; Argañosa et al., 1974/75; Popescu-Vifor, 1975; Belic et al., 1975; Gorin et al. 1976a and 1976b; Baik et al., 1977; Eliseev and Strelkova, 1977; Valarezo and Quijandria, 1979; Jancic et al. 1980b; Venev, 1981; Silver and Pavlik, 1982; Johansson and Kennedy, 1983; Zhang, 1983; Park and Kim, 1987; Chung and Park, 1987; Malyshev and Suslina, 1988; Triebler, 1989 and Zschorlich and Ritter, 1989). Thus, the estimate was in confirmation of the low heritability of the traits also in the herd in

Nepal. Nevertheless, many other estimates reported were slightly higher between 0.20 to 0.30 (Irvin and Swiger, 1977; Acta Genetica Sinica, 1977; Jancic et al., 1980a; Asling et al., 1980; Minutin and Svechin, 1981, Schlindwein and Duarte, 1981, Park and Kim, 1987 and Park et al., 1987), while even much higher estimates of 0.51, 0.54 and 0.72 were reported by Stankovic (1977), Chantsavanug (1977) and Young et al. (1978), respectively. Hence, the standard error of heritability estimate for the trait in this study which was in agreement with that reported by Toelle and Robison (1986) and Park et al. (1987) could also be considered fairly acceptable.

The heritability estimate of litter birth weight in this study was 0.144±0.241 which was very well in agreement with the several estimates reported between 0.10 and 0.20 (Vangelov, 1970; Gajic, 1974; Belic et al., 1975; Argañosa et al., 1974/75; Zhang, 1983; Alves et al., 1989; and Zschorlich and Ritter, 1989), while the literature range of estimates could be extended even wider to cover numerous other estimates reported from practically zero (Polyanichko, 1973) to as high as 0.77 (Chantsavang, 1977) with most other estimates (Walker et al., 1973; Irvin, 1976; Acta Genetica Sinica, 1977; Irvin and Swiger, 1977; and Kim et al., 1989) falling in this range but being higher than the estimate in the present study. The

relatively larger standard error of the estimate could, thus, be justified considering the possible sampling errors arising from a small data-set used in the study.

Table 6. Heritability estimates and standard errors of different litter performance traits in the swine herd in Nepal.

TRAITS	n	HERITABILITY ± S.E.
LSB	147	0.102 ± 0.193
LBW	147	0.144 ± 0.241
LSW	140	0.232 ± 0.179
PWT	140	0.229 ± 0.262
LWW	85	1.172 ± 0.926
AWW	85	0.409 ± 0.462

n = number of litters studied.

The heritability of litter size at weaning (LSW) was estimated at 0.232±0.279 which was consistent with that reported in Large White by Alves et al. (1989) and was close in agreement with other estimates of 0.24, 0.25, 0.21 and 0.25 reported by Edwards and Omtvedt (1970), Walker et al. (1973), Eliseev and Strelkova (1977) and Valarezo and Quijandria (1979), respectively. As the reports varied in the estimates from practically zero reported from 127 litters weaned at 56 days of age (Gupta

et al., 1983b) to 0.38 reported from 300 litters (Chantsavang, 1977), the finding of this study was within the literature range of estimates, despite the fact that most of the estimates from sizable data-set reported in the literature were very low, around 0.10 (Strang and king, 1970; Gajic, 1974; Stankovic, 1977; Chung and Park, 1987 and Kim et al., 1989). The standard error of the estimate in the present study was also close in agreement with that reported by Chung and Park (1987), Park et al. (1987) and Alves et al. (1989).

The heritability estimate of survival rate to weaning measured as the percentage of weaning based on total pigs born (PWT) was 0.229±0.262. This estimate could be considered moderate between a relatively higher value of 0.37±0.14 and another relatively lower value of 0.12±0.14 reported by Argañosa et al. (1974/75) and Park et al. (1987), respectively. Considering the standard error of 0.262, the estimate range in the present study could be accomodative even to 0.40 as the heritability estimate for survival rate from birth to 8 weeks of age reported by Cummings et al. (1947).

The heritability estimate of litter weaning weight adjusted to 42 days was 1.172±0.926 which could be considered extremely high with upward bias largely attributable to the maternal effects and the sampling

errors arising primarily from the adjustment of weaning weight to 42 day basis, as the heritability estimates of the trait as reported in the literature were generally low with most estimates falling in the range below from 0.29 (Edwards and Omtvedt, 1970) to even a negative estimate of -0.01 (Irvin, 1976). Nevertheless, other estimates in the literature, 0.40, 0.43, 0.72 and even 0.80 as reported by Argañosa et al. (1974/75), Eliseev and Strelkova (1977), Schlindwein and Duarte (1981) and Minutin and Svechin (1981), respectively were probably indicative of higher heritability associated with weaning at the ages from 42 to 56 days. Considering the extremely large standard error of heritability, the estimate in the present study could even be indicative of its possible lower limit which falls in the literature average.

The heritability estimate of average pig weaning weight adjusted to 42 days was 0.40±0.462. This was in agreement with the estimate of 0.40±0.14 reported by Argañosa et al. (1974/75) and was also comparable with heritability estimates of 0.43 and 0.37±0.02 for pig weaning weight reported in China (Acta Genetica Sinica, 1977) and India (Gupta et al., 1983a), respectively, although most other studies have revealed lower range of estimates. These estimates were in the range from very low values of 0.02, 0.03±0.02 and 0.05 reported by Vangelov

(1970), Strang and King (1970) and Bhatia and Sharma (1979), respectively to moderate values of 0.22, 0.186, 0.19, 0.21 and 0.16±0.17 reported by Polyanichko (1973), Popescu-Vifor (1975), Vasileva et al. (1978), Jancic et al. (1980b) and Park et al. (1987), respectively. The relatively larger standard error of the heritability estimate in the present study was not surprising considering the small data-set utilized in the estimation.

Genetic Correlations

The estimates of genetic correlations among six litter performance traits are presented in Table 7. The genetic correlations for some pairs of traits were greater than unity. However, these estimates exceeding their positive extreme limit were not unusual considering on the one hand, that a large sampling error could have been arisen from the relatively small data-set utilized in their estimation and on the other hand, that many published genetic correlations have been smaller than -1.0 or greater than 1.0 (Louca and Robison, 1967; Argañosa et al., 1969; Edwards and Omtvedt, 1971; Argañosa et al., 1974/75 and Young et al., 1978).

The genetic correlation (r_g) between LSB and LBW was 1.25 which was consistent with the estimate reported by Argañosa et al. (1974/75). The trend of this estimate was

at least indicative of a high positive correlation in agreement with the most of the published estimates which were in the range from 0.52 to 0.86 (Acta Genetica Sinica, 1977; Baik et al., 1977; Chantsavang, 1977; Milagres et al., 1983; Park and Kim, 1987; Alves et al., 1989; Kim et al., 1989 and Fonseca et al., 1989). The genetic correlation between LSB and LSW was also high and positive (r_g = 0.510±0.789) and was consistent with the estimates reported in the range from 0.52 to 0.86 (Park et al., 1987 and Alves et al., 1989), while many other estimates in the literature were much higher, close to unity (Argañosa et al., 1974/75; Milagres et al., 1983 and Fonseca et al., 1989) or even exceeding unity (Pham, 1972). The genetic correlation between LSB and PWT was weak (r_g = 0.113±1.027) and comparable in magnitude with the estimate of -0.17 reported by Argañosa et al. (1974/75), although their signs of covariance were in constrast. The genetic correlations of LSB with LWW and AWW were 1.031 and 1.592, respectively which were consistent with the those of LSB with LWW and pig weaning weight reported by Pham (1972). While the estimate for the former pair of traits was indicative of their high positive correlation in agreement with many other published estimates (Chantsavang, 1977; Alves et al., 1989 and Kim et al., 1989), the estimate for the latter pair was in contrast with other estimates,

-0.09 and -0.64 reported between LSB and pig weaning weight (Argañosa et al., 1974/75 and Milagres et al., 1983, respectively).

The genetic correlations of LBW with LSW and LWW were 1.228 and 1.034, which were consistent with those reported by Pham (1972) and Argañosa et al. (1974/75). These estimates were at least indicative of high positive correlations of the trait pairs following the trends with the estimates between 0.52 and 0.86, reported by Alves et al. (1989) and Kim et al. (1989). The genetic correlation between LBW and AWW was 1.486 which was also at least indicative of high positive correlation following the trend with estimates of 0.72 and 0.48, resported by Pham (1972) and Argañosa et al. (1974/75), respectively. The LBW was highly and positively correlated with PWT with r_g = 0.719±0.473 which was higher than the estimate of 0.25 reported by Argañosa et al. (1974/75).

The genetic correlation of LSW with PWT was very high and positive (r_g = 0.922±0.124). This was considerably higher than the estimate, 0.53 reported by Argañosa et al. 1974/75), although both of them followed a similar trend of high correlation. The genetic correlation of LSW with LWW was 1.164 which was indicative of high positive correlation between the pair of traits following the similar trend with many published estimates, close to

unity (Mahmud, 1970; Argañosa et al., 1974/75 and Young et al. 1978) and those reported between 0.52 and 0.86 (Pham, 1972; McCarter et al., 1987; Alves et al., 1989 and Kim et al., 1989). Similarly, the genetic correlation between LSW and AWW was 1.677 which was consistent with the estimate between LSW and pig weaning weight reported by Pham (1972), while the estimate reported by Argañosa et al. (1974/75) was also high and positive, although relatively much smaller in magnitude (r_g = 0.47).

The genetic correlations of PWT with LWW and AWW were high and positive with their estimates, 0.711±0.332 and 0.821±0.262 which were in close agreement with the estimates of PWT with LWW and pig weaning weight of 0.83 and 0.87, respectively reported by Argañosa et al. (1974/75).

The genetic correlation of LWW and AWW was 1.15 which should be at least indicative of high and positive genetic correlations of pair of traits following the trends of the genetic correlation of LWW with pig weaning weight with estimates, 0.7153, 0.80 and 0.53 reported by Pham (1972), Argañosa et al. (1974/75) and Acta Genetica Sinica (1977), respectively.

Thus, the genetic correlation estimates among the traits studied were generally set higher than most of the published estimates. However, some of the estimate in the

present study were either consistent or fairly in agreement with a number of estimates reported earlier, while other estimates have at least followed some trends similar to most of the published estimates. Furthermore, the relatively high values of standard errors for the estimates, largely due to sampling error of the data-set, were indicative of wider ranges that could accommodate most of the published estimates and were fairly comparable with the standard errors reported for some of the traits (Argañosa et al., 1974/75 and Young et al., 1978).

Phenotypic Correlations

Phenotypic correlations among six litter performance traits studied are presented in Table 7. The phenotypic correlation between LSB and LBW was positive and highly significant ($P<0.01$) with the correlation estimate of 0.648 which was consistent with the estimate of 0.62 reported by Pham (1972) and in considerable agreement with other estimates ≥ 0.76 reported by Edwards and Omtvedt (1971), Fahmy and Bernard (1972a), Argañosa et al. (1974/75), Young et al. (1978) and Park and Kim (1987). Similarly, a positive and highly significant ($P<0.01$) correlation of 0.542, was also evident between LSB and LSW, falling in agreement with several published estimates in the range from 0.49 (Park et al., 1987) to

0.82 (Pham, 1972; Young et al. 1978; Chung and Park, 1987 and Rhee et al., 1987). There was a moderate positive but highly significant ($P<0.01$) correlation between LSB and LWW with the coefficient, $r_p = 0.374$. This estimate was comparable with the estimate of 0.44 reported by Argañosa et al. (1974/75) and also with that reported in the range of 0.21-0.52, but was relatively lower than other published estimates, ≥0.5 (Omtvedt et al., 1966; Edwards and Omtvedt, 1971; Fahmy and Bernard, 1972a and Young et al., 1978). On the other hand, significant negative correlations of LSB with PWT ($P<0.01$) and AWW ($P<0.05$) were evident with their estimates, -0.234 and -0.216, respectively. The former estimate was consistent with the estimate of -0.24 reported by Argañosa et al. (1974/75) and was also in considerable agreement with other estimates of correlation between LSB and preweaning survival rate, -0.18, and -0.28 reported by Omtvedt et al. (1966) and Fahmy and Bernard (1972a), respectively. The correlation of LSB with AWW was -0.216 and was fairly close to many published estimates reported between -0.25 and -0.27 (Revelle and Robison, 1973; Argañosa et al., 1974/75 and Young et al., 1978), while there have been also reports of much lower estimates, -0.06 and -0.14 (Fahmy and Bernard, 1972a and Pham, 1972, respectively)

and much higher estimates, -0.59 (Omtvedt et al., 1966) and -0.36 (Young et al., 1978).

The phenotypic correlations of LBW with LSW and LWW were positive and highly significant ($P<0.01$) and were 0.503 and 0.512, respectively, which were in considerable agreement with the literature estimates of 0.60, 0.64 and 0.62 in the former case and 0.56, 0.69 and 0.52 in the latter case as reported by Omtvedt et al. (1966), Fahmy and Bernard (1972a) and Argañosa et al. (1974/75), respectively. On the other hand, there were positive but non-significant correlations of LBW with PWT and AWW, 0.026 and 0.020, respectively which were in close agreement in their magnitude, with the published estimates of -0.02 and -0.01 for the former pair of traits and 0.04 and -0.13 for the latter pair reported by Fahmy and Bernard (1972a) and Argañosa et al. (1974/75), respectively.

Phenotypic correlations of LSW with PWT and LWW were positive and highly significant ($P<0.01$) with their estimates of 0.663 and 0.669, respectively. Both of these estimates were comparable with high positive estimates in the range from 0.40 to 0.88 reported in the literature (Omtvedt et al., 1966; Strang and King, 1970; Edwards and Omtvedt, 1971; Argañosa et al. 1974/75 and McCarter et al., 1987) in the case of the former and the high positive

estimates of 0.53 and 0.52 reported by Fahmy and Bernard (1972a) and Argañosa et al. (1974/75), respectively in the latter case. The Phenotypic correlation between LSW and AWW was -0.187 and was significant at (P<0.05). This estimate was consistent with the estimate of -0.19 reported by Fahmy and Bernard (1972a), while it also followed the trend and direction of estimates, -0.51, -0.4 and -0.04 reported by Omtvedt et al. (1966), Strang and King (1970) and Argañosa et al. (1974/75), respectively.

The phenotypic correlations of LWW with PWT and AWW were positive and highly significant (P<0.01) and were 0.463 and 0.576, respectively. The former was not very far from the slightly higher estimates of 0.57, 0.52 and 0.55 reported by Omtvedt et al. (1966), Fahmy and Bernard (1972a) and Argañosa et al. (1974/75), respectively. However, the correlation estimate between LWW and AWW in the present study was relatively higher than the estimates between LWW and pig weaning weight reported in the range from 0.12 and 0.39 (Omtvedt et al., 1966; Fahmy and Bernard 1972a and Argañosa et al. 1974/75), although, their trend and direction was similar to the present findings. A non-significant low but positive correlation of 0.019 was evident between PWT and AWW. This was comparable in magnitude with the very low but negative correlation estimates of -0.04 and -0.08 between pig

weaning weight and percentage weaning of total pigs born reported by Omtvedt et al. (1966) and Fahmy and Bernard (1972a), respectively. However, the estimate in this study was much lower than the estimate of 0.34 reported by Argañosa et al. (1974/75).

Thus, the phenotypic correlations among all the traits studied were generally in agreement with most of the published estimates.

Variances and Covariances

Phenotypic variances and covariances measured as the total components of variances and covariances for six litter performance traits and their genetic variances and covariances based on their respective sire components (Appendix Tables 2.1-2.5 and 3.1-3.15) are summarized in Table 8 and Table 9, respectively. Phenotypic variances of LSB, LSW and AWW were 6.045, 5.663 and 3.640, respectively and were in close agreement with their respective estimates of 4.9902, 6.0086 and 3.7140 reported by Pham (1972). The phenotypic variance of 9.901 for LBW in this study was slightly lower than the estimate of 17.0803 reported by Pham (1972), while that of 388.602 for LWW in this study was much higher than its estimate of 221.8425 reported by Pham (1972). The phenotypic covariances among most of these traits were comparable with those reported

by Pham (1972) and the genetic variance of LWW and its genetic covariances with other traits were generally in close agreement with those reported by Pham (1972) except for its higher covariance with LBW in the Pham's estimate. Very small estimates of genetic variances and covariances for LSB, LBW and LSW were indicative of a very limited progress that could be achieved through selection for these traits.

Considerable amounts of phenotypic and genetic variances of PWT and its covariances with LWW were indicative of some possibility of success in the simultaneous selection for these two traits. However, estimates of heritability of LWW and its genetic correlations with other traits were inaccurate due to upward biases in this study and were unsuitable for use in the formulation of selection criteria. Although the variance of AWW and its covariances with most of other traits were very small, considerable magnitude of covariance both genetic and phenotypic between LWW and AWW was suggestive of its worthiness for consideration <u>in lieu</u> of LWW in the selection program.

Table 7. Phenotypic (above diagonal) and genetic (below diagonal) correlations among litter performance traits in the swine herd in Nepal.

TRAITS	LSB	LBW	LSW	PWT	LWW	AWW
LSB		0.648** (147)	0.542** (140)	-0.234** (140)	0.374** (85)	-0.216* (85)
LBW	1.25		0.503** (140)	0.026 (140)	0.512** (85)	0.020 (85)
LSW	0.510 ±0.789	1.228		0.663** (140)	0.669** (85)	-0.187* (85)
PWT	0.113 ±1.027	0.719 ±0.473	0.922 ±0.124		0.463** (85)	0.019 (85)
LWW	1.031	1.034	1.164	0.711 ±0.332		0.0576** (85)
AWW	1.592	1.486	1.677	0.821 ±0.262	1.159	

Note:
* = signigicant at (P<0.05); ** = significant at (P<0.01).
± = standard errors (S.E.s) of genetic correlations;
S.E.s were not computed for estimates greater than 1.00.
Figures in the parentheses correspond to the number of litters included in the study.

Table 8. Phenotypic variances (diagonal) and covariances (above diagonal) among litter performance traits in the swine herd in Nepal.

TRAITS	LSB	LBW	LSW	PWT	LWW	AWW
LSB	6.046	5.016	3.183	-12.244	17.715	-1.063
LBW		9.901	3.797	1.738	32.924	0.134
LSW			5.663	33.458	29.528	-0.858
PWT				449.528	158.367	0.674
LWW					388.602	20.214
AWW						3.640

Table 9. Genetic variances (diagonal) and covariances (below diagonal) among litter performance traits of the swine herd in Nepal.

TRAITS	LSB	LBW	LSW	PWT	LWW	AWW
LSB	0.155					
LBW	0.293	0.355				
LSW	0.137	0.445	0.328			
PWT	0.270	2.308	2.680	25.741		
LWW	8.323	10.255	10.068	38.126	113.842	
AWW	0.735	0.842	0.830	2.517	7.546	0.372

Relative Economic Weights

Considering the values of different parameters, namely heritabilities, phenotypic and genetic correlations, of the traits, a serious thought was given to select trait combinations to be included in the formulation of selection indices. PWT and AWW were selected as the traits of littermate gilts with the probable success from their simultaneous selection through an index. An attempt was also made to consider LSB and LBW for comparative purpose. Hence, the relative economic weights of these four traits were determined for the purpose of constructing selection indices using these traits.

As the individual producer supplied inputs could not be included in the litter production function due to lack of adequate data on the costs involved, an attempt of regression analysis of all litter performance traits at once on the litter output i.e. litter size at weaning (LSW) was not successful to derive a reliable model. However, stepwise regression analysis using backward elimination procedure for two trait combinations of PWT and AWW, and LSW and LBW separately on litter output (LSW) as presented in Appendix Tables 4 and 5, respectively were successful in yielding two significant final models with all the trait variables significant ($P<0.05$). The

resulting two production functions of litter output (LSW) expressed as respective regression models were:

1) $LSW = f(PWT, AWW)$

$= 1.502+0.098\ (PWT)-0.004\ (AWWxPWT)$

with the corresponding profit function,

$\pi = P_y \{1.502 +0.098(PWT) -0.004(AWWxPWT)\}$

$-P_{PWT} -P_{AWW} -COP;$

2) $LSW = f(LSB, LBW)$

$= 1.478+0.442\ (LSB) +0.163\ (LBW)$

with the corresponding profit function,

$\pi = P_y\{1.478 +0.442(LSB) +0.163(LBW)\}$

$-P_{LSB} - P_{LBW} -COP.$

Despite lower coefficients of variation, R^2 = 0.38 and 0.44, respectively for these two models all the trait variables representing the models were significant ($P<0.05$) and adequate in explaining the production functions for the purpose of determining their relative economic weights. The economic values, P_{PWT}, P_{AWW}, P_{LSB} and P_{LBW} for the trait variables, PWT, AWW, LSB and LBW, respectively and their relative economic weights were determined at the optimal level of production functions based on the average values, 9.435, 10.604 kg, 6.907, 75.296 % and 6.626 kg for the trait variables, namely LSB, LBW, LSW, PWT and AWW, respectively, the price (P_y) of

Rupees 400.00 prevailing in 1988 for a weanling pig as reported by Shrestha et al. (1988) and also the cost of production (COP) of Rupees 1797.70 which was assumed constant for a litter harvest (Shrestha et al., 1988) are presented in Table 10.

It was evident that the relative economic weight of an increase in the litter size by one unit was 2.71 times that of a kilogram increase in litter birth weight. On the other hand, the relative economic weight of a kilogram change in average pig weaning weight was 4.21 times greater than that of one unit change in percentage weaning of total born but in the opposite directions. The negative sign in the relative economic weight of AWW was due to the assumption that the prevailing output price of litter output (LSW) was fixed at Rs. 400.00 per weanling (Shrestha et al., 1988) irrespective of their weaning weights and also due the negative phenotypic correlation of AWW with LSW on which the regression analysis of the production function was based. Therefore, the present relative economic weightings may be changed considerably in the event that the output prices are based on weaning weights of piglets. Furthermore, the relative economic weights of the traits measured particularly at weaning should be considered conservative in this study, as the individual variation in the actual cost of production per

piglet in a litter was not included in the regression analysis due to nonavailability of the adequate information.

Table 10. Relative economic weights of selected litter performance traits in the swine herd in Nepal.

TRAIT-COMBINATION	TRAITS	ECONOMIC VALUES (Rupees)	RELATIVE ECONOMIC WEIGHTS
	LSW	400.00	As the basis
1. PWT -AWW:			
	PWT	28.60	1.00
	AWW	-120.47	-4.21
2. LSB -LBW:			
	LSB	176.80	2.71
	LBW	65.20	1.00

Selection Indices

The selection indices constructed on the basis of the parameters, namely phenotypic variances and covariances, genetic variances and covariances and relative economic weights of selected litter performance traits and their relative efficiencies computed as the correlation between the index and the aggregate genotypic value of the traits included are presented in Table 11.

Low correlations of these two indices with their respective aggregate genotypic values mainly attributed to low heritabilities, variances and covariances of the

traits, particularly LSB, LBW and PWT are indicative of their limited application in the simultaneous selection of the respective traits. However, in the absence of any other criteria of selection for the traits, the index particularly for PWT and AWW may be of some value.

Table 11. Swine selection indices and their relative efficiencies for selected litter performance traits in the swine herd in Nepal.

TRAIT-COMBINATION	SELECTION INDEX (I)	RELATIVE EFFICIENCY (r_{IT})
1. PWT -AWW:	I = 0.033PWT + 0.255AWW	25.88%
2. LSB -LBW:	I = 0.037LSB + 0.097LBW	21.20%

Study II: Growth Performance Traits

Means and Standard Errors

Means and standard errors of ADG, FCR and BFT in on-farm tested Nieuw Dalland pigs are presented in Table 12. The mean ADG in the on-farm tested marketable Nieuw Dalland hogs was 0.686±0.013 kg/day. This was more or less the same as the mean values, 657±1.09 g/day in gilts of three different breeds reported by Siagian (1984) and 691±3.97 g/day in boars belonging to purebred Pietrain Yorkshire, Duroc and crossbred Pietrain pigs reported by Napoles (1985); but was much lower than the mean values, 826 and 808 g/day, in imported boars and gilts, respectively, of three breeds reported by Argañosa et al. (1979).

The mean FCR in the on-farm tested hogs was 2.823±0.06 indicating a slightly lower feed efficiency when compared to the mean values of FCR in boars and gilts of different breeds reported by Argañosa et al. (1979), Siagian (1984), Argañosa et al. (1986) and Lambio et al. (1986) in the range between 2.45 and 2.68.

The mean backfat thickness in the on-farm tested hogs was 1.583±0.041 cm. This was extremely low and highly desirable compared to the mean values in the range from 2.2 to 2.75 cm in boars and gilts of different breeds as

reported by Argañosa et al. (1979), Siagian (1984), Argañosa et al. (1986) and Lambio et al. (1986). Thus, the hogs studied were relatively slower in growth rate and less efficient in feed consumption but leaner in pork than the pigs studied by most workers in the Philippines.

Table 12. Least square means and standard errors of production variables in on-farm tested Nieuw Dalland pigs.

VARIABLES	n	MEAN	± S.E.
Final weight, kg.	63	84.206	0.988
Average daily gain, kg	63	0.686	0.013
Feed conversion ratio	63	2.823	0.060
Backfat thickness, cm	41	1.583	0.041
Cost of production, ₱	63	2896.48	26.953

Note: n = Number of observations.

Phenotypic Correlations

Phenotypic correlations among the three traits ADG, FCR and BFT in hogs studied on-farm are presented in Table 13. ADG and FCR were highly but negatively correlated with coefficient, r_p = -0.816 ($P<0.01$) which was in close agreement with their correlation estimates, -0.66, -0.67 and -0.70, reported by Smith et al. (1962) for British

Large White pigs, by Smith and Ross (1965) for British Landrace pigs and by Chyr (1980), respectively. This was also similar in trend with the correlation coefficient, r_p = -0.53 reported by Lambio et al. (1986).

The phenotypic correlation between ADG and BFT was highly and positively significant ($P<0.01$) with its coefficient, r_p=0.526 which was consistent with the correlation (r_p =0.55) reported by Sutherland (1958, as cited by Hutchen and Hintz, 1981) and similar in trend with the correlation (r_p =0.25) reported by Chyr (1980). However, it was relatively higher than many estimates of the correlation from negative values, -0.08 (Smith and Ross, 1965), -0.34 (Reutzel and Sumption, 1968), -0.26 (Clarke et al., 1975) and -0.07 (Young et al., 1978) to positive correlations ranging from 0.03 to 0.16 (Zoeneller et al., 1963; Roy et al., 1968; Edwards and Omtvedt, 1971; Hetzer and Miller, 1972; Curran, 1973; Young et al., 1974; McPhee et al., 1979; Hutchens and Hintz, 1981 and Lambio et al., 1986).

The phenotypic correlation between FCR and BFT in the on-farm tested pigs was high and negative with r_p = -0.564 ($P<0.01$) in contrast to positive correlation estimates, 0.19, 0.44 and 0.34 reported by Smith et al. (1962) for British Large White pigs, by Smith and Ross (1965) for British Landrace pigs and by Chyr (1980),

respectively. Lambio et al. (1986) reported a negative correlation of -0.03 which, however, was lower than the value obtained in the present study.

Variances and Covariances

The phenotypic variances and covariances among the traits studied are presented in Table 14. The phenotypic variance of ADG was 0.0114 in this study and was in agreement with the estimates of Reimer (1959), Stanislaw (1966) and Webb and King (1976) which were around 0.01 as all cited by Hutchens and Hintz (1981). The weighted average of the variances from 20 studies was reported by Hutchens and Hintz (1981) to be slightly lower, 0.0061. The Phenotypic variance of FCR in this study was 0.229 which was slightly higher than that computed from the standard deviation of 0.260 for the trait reported by Rothschild et al. (1981) in various breeds of swine. The phenotypic variance of BFT, 0.0675 in the present study was close to the estimates of Wong (1969) and Webb and Jing (1976) which were 0.9018 and 0.0961, respectively, both cited by Hutchens and Hintz (1981) but was relatively lower than a weighted average of 0.2015 computed by Hutchens and Hintz (1981) from 19 studies, while Stockhausen and Boylan (1966) reported the estimate as high as 0.4130.

The Phenotypic covariances of ADG-FCR and ADG-BFT pairs of traits in this study were -0.416 and 0.0108, respectively, which were higher than those reported by Lambio et al. (1990b) who expressed ADG in the unit of g/day. The phenotypic covariance between FCR and BFT was -0.046 in this study, whereas Lambio et al. (1990b) reported a very low but positive estimate.

Table 13. Phenotypic (Pearson's) correlations of ADG, FCR and BFT in on-farm tested Nieuw Dalland pigs.

TRAITS	ADG	FCR	BFT
ADG		-0.816**	0.526**
		(63)	(41)
FCR			-0.564**
			(41)

Note:
** = significant at P<0.01.
Figures in the parenthesis correspond to the number of observations.

Table 14. Phenotypic variances (diagonal) and covariances (above diagonal) of ADG, FCR and BFT in on-farm tested Nieuw Dalland pigs.

TRAITS	ADG	FCR	BFT
ADG	11347.67	-41.602	10.815
	(62)	(62)	(40)
FCR		0.229	-0.046
		(62)	(40)
BFT			0.068
			(40)

Note: Number in the parentheses correspond to the degrees of freedom.

The genetic variances and covariances among ADG, FCR and BFT for on-farm tested pigs computed on the basis of genetic parameters from literature estimates (Table 15) are presented in Table 16. The genetic variances of ADG and BFT computed using their phenotypic variances in this study and the literature estimates of their heritability and genetic correlations (Table 15) were 0.0056, and 0.0668, respectively which were consistent with the estimates of 0.005 and 0.060 reported in crossbred and purebred gilts by Hutchens et al. (1981) and were also fairly close to literature averages of 0.0023 and 0.0786, respectively computed by Hutchens and Hintz (1981). The genetic variance of FCR was 0.0618 in this study.

The genetic covariances of ADG-FCR and ADG -BFT, -0.0097 and 0.0046, respectively in this study were generally higher than those estimates in Yorkshire and Landrace pigs as reported by Lambio et al. (1990b) on the basis of ADG expressed in g/day unit. The genetic covariance between FCR and BFT was zero due to the genetic correlation estimate between the two traits (Lambio et al. 1986) considered to be zero, while the genetic covariances of -0.00188 and -0.000469 in Yorkshire and Landrance, respectively for the two traits were reported by Lambio et al. (1990b). Nevertheless, these figures are fairly comparable with the results of the present study.

Table 15. Literature estimates of heritabilities (diagonal) and genetic correlations (below diagonal) of ADG, FCR and BFT in three breeds of pigs combined.

TRAITS	ADG	FCR	BFT
ADG	0.58±0.06		
FCR	-0.52	0.27±0.04	
BFT	0.24	0.00	0.99±0.09

Source: Lambio et al. (1986).

Table 16. Genetic variances (diagonal) and covariances (below diagonal) of ADG, FCR and BFT for on-farm tested Nieuw Dalland pigs, computed on the basis of genetic parameters reported by Lambio et al. (1986).

TRAITS	ADG	FCR	BFT
ADG	6581.6		
FCR	-10.504	0.062	
BFT	5.040	0.00	0.067

Production Function

The average cost of production of on-farm tested Nieuw Dalland pigs on the basis of assumptions of technical coefficients listed in Appendix Table 6 is presented in Table 17. Results showed that cost of production and the out-put were in just about a break-even point even at an interest rate of agricultural loan, 18% which is much lesser than that of prevailing commercial interest rate on capital. Nevertheless, considering the fact that the substantial profit being obtained from the price of initial stock was not accounted for in the present study and considerably high investment in housing and equipment facilities was meant for training purposes rather than for actual need at optimum level of production, the farm could still be considered making profits in real terms. Since the price of initial stock considered was inclusive of the feed cost incurred from birth to initial age, the total feed cost could not be ascertained. Nevertheless, when the price of initial cost was excluded, the remainder cost of production was fairly close to the average production cost per animal without cost of weanling reported by Salayog (1977) in terms of percentage of its component costs except for his slightly high estimation of feed cost (87%) probably due to differences in efficiencies of the animals studied. In the

present study, the feed cost was the major component comprising 69.67% of total cost of production, while non feed cost was 31.33% when the initial price of the pig was excluded.

The regression analysis of second order Taylor-series expansion of inputs, ADG, FCR, BFT and total cost of production (COP) on the final weight (FWT) presented in Appendix Table 7 revealed that the first-order variables were highly significant ($P<0.01$) while all second order variables were non significant ($P<0.05$). Even the step-wise regression analysis with backward elimination procedure was not successful in retaining any of second order terms and was eliminating all terms involving BFT and hence this procedure was abandoned. However, the multilinear regression analysis of ADG, FCR, BFT and COP on FWT as presented in Appendix Table 8 was highly significant ($P<0.01$) with the coefficient of determination, R^2 = 96.9% and coefficient of variation (CV), 1.8% indicating the perfect fit of the model. Hence, the following final multilinear model was considered as the production function of the animals studied:

$$FWT = 25.09736 + 10.44744(ADG) - 15.2005(FCR) + 1.6745(BFT) + 0.03209(COP).$$

Table 17. Average values of producer supplied inputs of production function and output of Nieuw Dalland market hogs[1].

VARIABLES	AVERAGE	STANDARD DEVIATION	% COST OF TOTAL COST
Initial age	86.9 days	19.8	-
Initial weight	29.4 kg	7.11	-
Final age	166.0 days	18.2	-
Final weight	84.2 kg	7.78	-
Days on test	79.8 days	12.3	-
Total gain in weight	54.7 kg	9.5	-
Initial cost of pig	P 1479.36	249.30	51.04
Interest on land	P 11.72	1.82	0.40
Depreciation on housing	P 47.21	7.33	1.63
Interest on housing investment	P 127.46	19.78	4.40
Repairs and maintenace cost of housing	P 23.60	3.66	0.81
Major equipment cost[2]	P 32.82	5.09	1.13
Minor equipment cost[2]	P 4.94	0.76	0.17
Lobor cost	P 69.89	18.85	2.41
Veterinary drugs/ disinfectants	P 27.96	4.34	0.97
Water cost	P 5.03	0.78	0.17
Electricity cost	P 5.39	0.83	0.18
Feed cost	P 988.568	149.78	34.11
Interest on working capital	P 74.48	10.88	2.57
Average total cost	P 2898.54	215.13	100.00
Sales of market hog	P 2899.23	267.92	-

[1] Based on observations of 63 on-farm tested pigs.
[2] Depreciation and interest on capital investment.
P = Pesos.

Economic Values of Traits

The corresponding profit function of the production function illustrated above was as follows:

$$\pi = 34.43\ (25.09736 + 10.4474ADG - 15.20051FCR + 1.67453BFT + 0.03209COP) - P_{ADG}(ADG) - P_{FCR}(FCR) - P_{BFT}(BFT) - COP;$$

where P_{ADG}, P_{FCR} and P_{BFT} are the economic values of ADG, FCR and BFT, respectively.

The economic values of ADG, FCR and BFT determined at the optimum level of the profit function were Pesos 359.70, - 523.35 and 57.65, respectively.

It was difficult to make direct comparisons of the economic values of the traits in the present study with those reported across other countries due to differences in price structures and currency exchange rates in different countries over the years in which studies were made. However, their relative economic weights should provide adequate basis for such comparisons. The comparative relative economic weights of the ADG, FCR and BFT across studies are presented in Table 18. The relative economic weights of these three traits in the present study were found to be 6.249, -9.088 and 1.00, respectively. The finding of the present study that the relative economic weight of ADG was less than that of FCR was similar in trends to the findings reported by several

workers (Bereskin, 1977; Chyr, 1980 and Mitchell et al., 1982) but the difference between values of the two traits was relatively small in those reports as compared to this study. Bereskin (1977) and Chyr (1980) reported economic values for the two traits to be Pesos 590.19 and 716.88 in the United States and 590.19 and 603.58, Taiwan, respectively as converted at the exchange rates of Pesos 28.00 per U.S. Dollar prevailing in the Philippines at the end of the year 1990. The relative economic weights of ADG and FCR recommended by National Swine Improvement Federation (NSIF) in the United States (Rothschild et al., 1981) were 4.00 and -9.00, respectively which also followed similar trend. There have been also several other reports (Minkema et al., 1964; Cunningham, 1978 as cited by Chyr, 1980 and Rothschild et al. 1981) showing that the relative economic weight of ADG was slightly greater than that of FCR. Nevertheless, ADG and FCR in these studies appeared to be not very far from equality in their relative economic weights. On the other hand, the ratio between relative economic weights of ADG and FCR in this study was 1:1.45 which was fairly comparable with the ratio of 1:1.67 as obtained from the economic weights of these traits estimated by Morris et al. (1978).

The economic value of BFT varied extremely across studies from its relative economic weight more or less

equal to that of ADG and FCR (Chyr, 1980 and Rothschild et al., 1981) to much smaller value compared to that of other two traits. Its relative economic value reported earlier by Bereskin (1977) was little less than one sixth of that of ADG and BFT, while Cunningham (1978) as cited by Chyr (1980), reported its value to be about one seventh of the value of ADG and little less than one fourth of that FCR. As the relative economic weight of BFT in relation to ADG and FCR in most studies were dependent on the relative emphasis given to these traits in their respective production systems, the finding of a low relative economic weight of BFT in this study was justified under the Philippine conditions.

Clearly in this study, results have indicated that the producer has been giving most emphasis on feed efficiency followed by growth rate of pigs, while the backfat thickness has not yet been economically much of a consequence with the absence of a premium price of leaner hogs marketed on live weight basis. Hence, the relative economic weights of the three traits studied under the Philippine conditions appeared to be clearly different from those reported abroad (Table 18,) particularly with the lower value of decreasing one unit of backfat thickness.

Table 18. Comparative data on relative economic weights* of ADG, FCR and BFT across various studies.

AUTHOR/S	COUNTRY OF STUDY	RELATIVE ECONOMIC WEIGHTS		
		ADG	FCR	BFT
Minkema et al. (1964)[a]	Netherlands	2.00	1.34	1.00
Bereskin (1977)[a]	U.S.	6.30	6.44	1.00
Cunningham (1978, as cited by Chyr, 1980)[a]	U.K.	6.90	4.15	1.00
Morris et al. (1978)[b]	New-Zealand	7.20	12.00	0.60+
Chyr (1980)[a]	Taiwan	1.21	1.47	1.00
Rothschild et al. (1981)	U.S.[1]	4.00	9.00	3.50
	U.S.[2]	5.48	6.15	3.50
	U.S.[3]	3.16	2.60	3.50
	U.S.[4]	5.04	2.78	3.50
	U.S.[5]	4.00	3.34	3.50
	U.S.[6]	2.69	2.73	3.50
Mitchell et al. (1982)[a]	U.K.	1.00	1.23	-
This study	Philippines	6.24	9.08	1.00

Note:

*Shown without their signs of directional change.
U.S. = United States; U.K. = United Kingdom.
[a]Relative economic weights computed from the economic values reported.
[b]Economic values in New Zealand Dollars.
[1]Recommended by NSIF;
[2]Computed from Iowa Index;
[3,4,5,6]Relative economic weights in Duroc, Hampshire, Spotted and Yorkshire pigs, respectively.
+ Based on ultrasonic fat depths measured in mm.

Selection Index

The selection index (I) constructed in this study on the basis of phenotypic variances and covariances, genetic variances and covariances and also the relative economic weights of ADG, FCR and BFT from on-farm tested Nieuw Dalland market hogs is forwarded as:

$$I = 4.256\ (ADG) - 2.078\ (FCR) - 0.682\ (BFT).$$

Rescaling for simplicity avoiding the negative index score for any animal on test, the index can be rewritten as:

$$I = 200 + 42.56\ (ADG) - 20.78\ (FCR) - 6.82\ (BFT).$$

The index coefficients (b's) for ADG, FCR and BFT in this index are in their proportions of 1.00: -0.49: -0.16 indicating that the relative emphasis given to FCR was slightly higher and that given to BFT was slightly lower, as compared to the U.S. index developed at Iowa State University in which case the b's for the three traits were 110, -50 and -19.7 in the proportions of 1.00: -0.46: -0.18, respectively. However, these differences in the proportions of b's were relatively small as compared to a boar selection index developed in Taiwan (Chyr, 1980) with the b's of 60, -40 and -45 for the three traits in the proportions of 1.00: -0.67: -0.75, repectively.

The variance of the index in this study , $\underline{b}^T.P.\underline{b}$ was 1.77, while the variance of the aggregate genotypic value

for the three traits considered, $\underline{a}^{T}.G.\underline{a}$ was 6.534. Hence, the relative efficiency of the index (I) expressed as the correlation between the index and aggregate genotypic value (T), i.e. r_{IT} was 0.5205 which was comparable with the correlations of 0.46 and 0.65 for the indices built by Cunningham (1978 as cited by Chyr, 1980) and Chyr (1980), respectively. This was indicative of a considerably high reliability of the index, provided that all the assumptions particularly the genetic parameters from literature estimates used in the construction of the index were true for the herd studied.

The index constructed in this study was intended for use in the on-farm performance testing of pigs in the selection of the breeding replacement for the three traits. Due to its close resemblance to the Iowa index, which is currently in use in the boar performance testing in the Philippines, the possibility of its use to the extent of replacing the Iowa index could also be considered.

SUMMARY AND CONCLUSION

This work was an attempt to address the important aspects of estimation of parameters essential in the construction of swine selection indices under two distinct categories of countries in Asia exemplified by, on the one hand, Nepal where swine raising has been mainly a supporting livelihood activity of subsistence farmers and the swine litter performance, at the present stage, has been given some importance due to increasing demand of weanlings of improved breeds, and on the other hand, the Philippines where swine herds represent a major component of the livestock industry and their production efficiencies have been considered increasingly important.

In the case of Nepal, an attempt was made, for the first time, to estimate genetic parameters such as heritabilities and genetic correlations of six litter performance traits, namely litter size at birth (LSB), litter birth weight (LBW), litter size at weaning (LSW), percentage weaning of total pigs born (PWT), litter weaning weight (LWW) and average pig weaning weight (AWW) based on sire component of variance from the data of 147 litters born in five years to 59 sows and seven boars of Landrace, Yorkshire and their crosses. Results obtained showed that the heritability estimates of the traits associated with litter sizes, viz. LSB, LSW and PWT and

also LBW were either consistent with or close to the generally very low estimates in the literature. However, those associated with the weaning weights were inclined to be high, as the estimate of LWW was extremely biased upward exceeding unity, while that of AWW was comparable with the higher set of estimates reported in the literature. Similarly, the genetic correlations among the traits studied were generally very high and positive with their estimates either extremely biased upward exceeding unity or comparable with higher set of estimates reported in the literature. Large standard errors of these genetic parameters were evident due to sampling errors arisen from the maternal effects and small data-set analysed.

The phenotypic correlations among the litter performance traits studied were generally in agreement with those reported in the literature. Highly significant and positive correlations were evident among most of the traits except in some cases of PWT and AWW, both of which were negatively correlated with LSB and non-significantly but positively correlated with LBW, while AWW was negatively correlated with LSW and non-significantly but positively correlated with PWT.

Two selection indices constructed on the bases of relative economic weights which were found to be in the ratios of 1.00:-4.21 and 2.71:1.00 for PWT-AWW and LSB-LBW

trait pairs, respectively, genetic variances and covariances, and phenotypic variances and covariances among these traits revealed their considerably low relative efficiencies of 25.88 and 21.20%, respectively. Clearly, the use of these indices in the selection of their respective pairs of traits is limited. However, in the absence of any other selection criteria, use of particularly the index involving PWT and AWW may be of some value in the selection of littermates as the replacement stock. It is also recommended that a sensitity analyses of the relative economic weights estimated in this study should be conducted with the inclusion of as many available producer-supplied inputs as possible in the production function to determine the final validity of these weightings. Furthermore, the importance of accurate recording of the trait measurements needs to be emphasized for future attempts of genetic evaluation of swine herds in the country so that most records of the however small herd sizes available could be included to facilitate more accurate estimation of parameters.

In the Philippine case, the phenotypic correlations among the most important growth performance traits, namely average daily gain (ADG), feed conversion ratio (FCR) and backfat thickness (BFT) were estimated from the data on on-farm testing of forty two barrows and twenty one gilts

of a Nieuw Dalland commercial herd. Results that a high and positive correlation was existent between ADG and BFT both of which, in turn, were highly and negatively correlated with FCR, were generally in close agreement with many of the published estimates. The corresponding phenotypic variances and covariances among the traits estimated in this study were generally either in agreement with or slightly higher than some published estimates.

The genetic variances and covariances among the three traits computed using the estimates of their heritabilites and genetic correlations available in the Philippine literature and the phenotypic parameters estimated in this study could be considered conservative due to the use of the literature estimates of genetic parameters and should be used cautiously.

The relative economic weights of ADG, FCR and BFT determined on the basis of average observed values of the traits, available producer-supplied inputs and their prices and output price, included in a highly fitting model of a specified production function of the on-farm tested marketable hogs were 6.24, -9.08 and 1.00, respectively which were clearly different from those reported in other countries, particularly due to the very low economic value of BFT in this study.

A selection index involving ADG, FCR and BFT constructed using the parameters derived in this study for use in the performance testing of pigs had its relative efficiency of 52.02%. This was indicative of a considerably high reliability of the index which could be possibly used to achieve considerable genetic progress, provided that all the assumptions particularly of the literature estimates of genetic parameters used in this study were true for the herd studied. Clearly, a thorough genetic evaluation of the herd is needed further to verify these assumptions. Furthermore, a wide scale genetic evaluation of swine herds and sensitivity analyses of the economic values of the traits suggested in this study, considering possible changes in the producer-supplied inputs in different herds are recommended for the future attempts of development of a selection index widely applicable in the country.

LITERATURE CITED

ABILAY, T.A., E.M. RIGOR, E.D. BELTRAN, F.F. PEÑALBA and C. LANDICHO. 1976. Four-year feedlot performance of the NSDB-UPLB developed triple cross and various standard purebreds. Anim. Husbandry and Agric. J. 11: 5: 4-8.

ACTA GENETICA SINICA. 1977. Inheritance of some quantitative traits in Hwai pigs. Anim. Breed. abstr. 45: 3: p.191.

ALVES, R.G.DE. O., M.DE.A.E. SILVA, J.A.A. PEREIRA, A.B.J. SANCEVERO and A.S. BARBOSA. 1989. Effect of environmental and genetic factors on pig litter size and weight at birth and 21 days of age. Anim. Breed. Abstr. 57: 2: p.123.

AMIR, P and H.C. KNIPSCHEER. 1989. Conducting on-farm Animal Research: Procedures and Economic Analysis Winrock and IDRC.

ANDREEV, A., I. VASILEVA and P. MISHEV. 1979. Genetic and statistical parameters of fertility and milk production of sows. Anim. Breed. Abstr. 47: 11: 672.

ANONYMOUS.1979. Breeding value test : pig. Anim. Breed. Abstr. 47: 10: 575.

ANONYMOUS. 1988. Lampatan livestock Research Station, Pokhara, Nepal. Annual Report 2044/45.

ARGAÑOSA, V.G. 1968. The influence of genetic factors on pork quality. Unpublished Ph.D. Thesis. Oklahoma State University, Stillwater, U.S.A.

ARGAÑOSA, V.G., N.M. BREBANTE and C.L. LUMABIANG. 1990a. Evaluation of the reproduction performance of Farm EDW, a chosen swine Farm. Anim. Husb. & Agri. Jour. 24: 10: 11-13.

ARGAÑOSA, V.G., O.M. GATMAITAN and M.O. VILLETA. 1990b. Evaluation of the reproductive performance of Farm LVY, a chosen Farm. Anim. Husb. & Agri. Jour. 24: 5: 10-12.

ARGAÑOSA, V.G., I.T. OMTVEDT and L.E. WALTERS. 1969. Phenotypic and genotypic parameters of some carcass traits in swine. J. Anim. Sci. 28: 168.

ARGAÑOSA, V.G., F.F. PEÑALBA and P.F. ALCANTARA. 1974/75. Genetic and phenotypic parameters of traits associated with sow productivity. Phil. Agriculturist. 58: 7/8: 229-307.

ARGAÑOSA, V.G., J.V. SERRANO Jr. and R.P. REYES. 1979. Production performance of Imported Landrace, Welsh, Yorkshire, and synthetic line of swine from England. Phil. J. Vet. Anim. Sci. 5: 3: 170-178.

ARGAÑOSA, V.G., P.H. SIAGIAN, A.G. AQUINO, C.C. LOPEZ, A.L. DE GUZMAN and D.V. MATEO. 1986. Productive performance of Yorkshire, Landrace and Duroc boars. Phil. Agriculturist. 69: 119-129.

ASLING, I., J. KRIPPL and F. PIRCHNER. 1980. Maternal effects on reproductive traits in pigs. Paper, 30th Animal meeting European Association for Animal production. Anim. Breed. Abstr. 48: 12: p. 885.

BAIK, D.H., D.H. PARK, B.K. OHH and S.W. HAN. 1977. Heritability, repeatability and genetic correlations among litter size, litter weight and gestation length in swine. Anim. Breed. Abstr. 45: 4: p.241.

BECKER, W.A. 1975. Manual of quantitative genetics. Third editon. Washington State University. Pullman, Washington.

BELIC, J., Z. GAJIC and V. ISAKOV. 1975 Reproductive performance of Subotica White pigs. Anim. Breed. Abstr. 43: 12: p.688.

BERESKIN, B. 1977. Evaluating and using performance records of boars at central testing station USDA. ARS-NE- 82.

BERNARD, G.S., A.B. CHAPMAN and R.H GRUMMER. 1954. Selection of pigs under farm conditions: Kind and amount practiced and a recommended selection index. J. anim. Sci. 13: 389.

BERRUECOS, J.M., E.U. DILLARD and O.W. ROBISON. 1970. Selection fo low backfat thickness. J. Anim. Sci. 30:6: 844-848.

BHATIA,S.S., and P.K. SHARMA. 1979. Genetic studies on some economic traits in Landrace pigs. Indian Vet. Journal 56: 1: 45-48.

BRUNER, W.H. and L.A. SWIGER. 1968. Effects of sex, season and breed on live and carcass traits at the Ohio swine evaluation station. J. Anim. Sci. 27: 2: 383-388.

BUCHANAN, D.S. and W.G. LUCE. 1985. The relationship between performance and selling price for boars tested at the Oklahoma Swine Evaluation. Anim. Sci. Res. Report. MP-117: 41.

CHANTSAVANG, S. 1977. Genetic parameters and inbreeding effects for preweaning traits in swine. Anim. Breed. Abstr. 45: 10: p.570.

CHRISTIAN, R.E. 1957 . The relative emphasis placed on components of a selection index under two nutritional environments. J. anim. Sci. 16: 2: 349.

CHUNG, H.W. and Y.Z. PARK. 1987. Heritabilities and genetic correlations between litter size at birth and number of suckled per litter in swine. Anim. Breed. Abstr. 55: 7: p.558.

CHYR, S.C. 1980. Swine selection index and direction of pig improvement. J. Chin. Soc. Anim. Sci. 9: 1-2: 55-69.

CLARKE, J.N., J.L. ADAM and K. HARGREAVES. 1975. Estimates of genetic variation and covariation from New Zealand national boar performance testing data. Anim. Breed. Abstr. 44: 192.

COP, W.A.G. and J. STELWAGEN. 1971. Current results of performance at the selection and fattening farm,"Zuid Nederland". Anim. Breed. Abstr. 39: 1: 125.

COSTA, C.N., W.H. SARALEGUI, J.A. FAVERO AND G.R. LEITAO. 1987. Genetic parameters and selection indices for pigs. Anim. Breed. Abstr.55: 4: 294.

CRAFT, W.A. 1958. Fifty years of progress in swine breeding. J. Anim. Sci. 17: 960.

CUMMINGS, J.N., L.M. WINTERS AND H.A. STEWARY. 1947. The heritability of some factors affecting productivity of breed sows. J. Anim. Sci. 6: 297.

CUNNINGHAM, E.P. 1969a. The relative efficiencies of selection indices. Acta Agri. Scand. 19: 45-48.

CUNNINGHAM, E.P. 1969b. Animal Breeding Theory. Institute of Animal Genetics and Breeding, Universitets forlaget, Vollebekk/Oslo.

CURRAN, M.K. 1973. ' On-farm ' performance testing of pigs in Britain. Wld. Rev. of Anim. Prod. 9: 4: 58-63.

DATACON, 1990. Management Information Report: Price monitor survey. Data consultant service center. Muntinlupa, Metro Manila.

DE ONON, E.M. 1974. The performance of some improved strains of pigs and various purebreds in the Philippines. Unpublished M.S. Thesis. UPLB, College, Laguna. 50 pp.

DEO, S., B.L. RAINA and P.N. BHAT. 1980. Studies on some reproductive traits in Landrace, Large White and their half-breeds. Anim. Breed. Abstr. 48: 12: p.886.

DICKERSON, G.E. 1960. Techniquies for research in quantitative animal genetics. In: Techniquies and Procedures in Animal Production Research. American Society for Animal Production. N.Y. pp.36-76.

DIEGUEZ, F.J. and M. CASTRO. 1974. Growth performance and carcass composition of Yorkshire, Duroc Jersey, Hampshire and Landrace pigs. Anim. Breed. Abstr. 42: 2: 616.

DIEGUEZ, F.J.,F. MARTINIZ and G. TRUJILLO. 1979. Growth and backfat thickness at 7 months of age in three types of gilts. Anim. Breed. Abstr. 47: 9: 538.

EDWARDS, R.L. and I.T. OMTVEDT. 1970. Genetic aspects of sow productivity, growth rate and backfat thickness. Anim. Breed. Abstr. 38: 4: p.637.

EDWARDS, R.L. and I.T. OMTVEDT. 1971. Genetic analysis of a swine control population. II. Estimation of population parameters. J. Anim. Sci. 32: 185.

EISENHART, C. 1947. The assumptions underlying the analysis of variance. Biometrics. 3: 1: 1- 21.

ELISEEV, YU.K. and T.V. STRELKOVA. 1977. Heritability of economically important traits in Large White pigs at

the "Vozrozhdenie" breeding farm, Gorky region. Anim. Breed. Abstr. 45: 10: p.570.

FABBRI, R. and E. BERGONZINI. 1981. Characteristics of purebred and crossbred Duroc pigs. Anim. Breed. Abstr. 49: 8: 546-547.

FAHMY, M.H. and C.S. BERNARD. 1972a. Interrelationship between Reproductive traits in swine. Can. J. Anim. Sci. 52: 39-45.

FAHMY, M.H. and C.S. BERNARD. 1972b. Reproductive performance of gilts from lives selected for feed utilization and carcaes score. Can. J. Anim. Sci. 52: 267-271.

FALCONER, D.S. 1981. Introdution to quantitative genetics. 2nd Ed. Longman Group , England. pp. 340.

FLOCK, D.K. 1970. Genetic parameters of German Landrace pigs estimated from different relationships. J. Anim. Sci. 30: 6: 839-843.

FONSECA, N.A., J.C. MILAGRES, J.A.A. PEREIRA and M.DE.A SILAVA. 1989. Productivity of crossbred sows in a commercial herd at Jequeri, Mines Gerais. 5 genetic parameters. Anim. Breed. Abstr. 57: 7: p.628.

GAJIC, Z. 1974. Heritability of some reproductive traits in Large White pigs. Anim. Breed. Abstr. 42: 10: p.509.

GORIN, V.T., I.N. NIKITCHENKO and S.D. IVANUSHKIN. 1976a. Comparison of different methods of estimating heritability of some production traits in sows. Anim. Breed. Abstr. 44: 11: p.589.

GORIN, V.T., I.N. NIKITCHENKO and A.K. MISCHENKO. 1976b. Genetic and population parameters of development and performance of sows from some pedigree herds in White Russia. Anim. Breed. Abstr. 44: 11: p.589.

GUPTA, R.N., S.N.S. PAMAR and K.S. JOHAR. 1983a. Note on the effect of sire, sex and year on weaning weight of Large White Yorkshire pigs. Anim. Breed. Abstr. 51: 5: p.360.

GUPTA, R.N., S.N.S. PAMAR and K.S. JOHAR. 1983b. Note the study of litter size at birth and weaning in Large

White Yorkshire pigs. Anim. Breed. Abstr. 51: 6: p.464.

HALE, O.M. and B.L. SOUTHWELL. 1967. Difference of swine performance and carcass characteristics because of dietary protein level, sex and breed. J. Anim. Sci. 26: 2: 341-344.

HALEY, C.S., E. AVALOS and C. SMITH. 1988. Selection for litter size in the pig. Anim. Breed. Abstr. 56: 5: p.317-332.

HANSON, H.D. and H.W. JOHNSON. 1957. Methods for calculating and evaluating a general selection index obtained by pooling information from two or more experiments. Genetics. 42: 4: 421-432.

HARVEY, W.R. 1960. Least squares analysis of data with unequal subclass numbers. ARS 20-8 Biom. Service. ARS, U.S.D.A.

HAZEL, L.N. and J.L. LUSH. 1942. The efficiency of the three methods of selection. J. Heredity 33: 293.

HAZEL, L.N. 1943. The genetic basis for constructing selection indexes. Genetics, 28: 476.

HEADY, E.O. and J.L. DILLON. 1961. Agricultural Production Functions. Iowa State Press, Ames, Iowa.

HETZER, H.O. and R.H. MILLER. 1972. Rate of growth as influenced by selection for high and low fatness in swine. J. Anim. Sci. 35: 730.

HOGSETT, M.C. and A.W. NORDKOG. 1958. Genetic-economic value in selecting for egg production rate, body weight and egg weight part 2. The Genetic consequences of selection using an index for egg size, body weight and egg production rate. Poul. Sci. 37: 5: 1412-1419.

HUTCHENS, L.K. and R.L. HINTZ. 1981. A summary of genetic and phenotypic statistics for pubertal and growth characteristics in swine. Oklahoma State university, Agri. Exp. Sta. Tech. Bull. T-155.

HUTCHENS, L.K., R.L. HINTZ and JOHNSON. 1981. Genetic and phenotypic relationships between pubertal and growth characteristics of gilts. J. Anim. Sci. 53: 4: 946-951.

IRGANG, R. and O.W. ROBISON. 1984. Heritability estimates for age at farrowing, rebreeding interval and litter traits in swine. J. Anim. Sci. 59: 1: 67-73.

IRVIN. K.M. 1976. Genetic parameters and selection indexes for sow productivity. Anim. Breed. Abstr. 44: 7: p.373.

IRVIN, K.M. and L.A. SWIGER. 1977. Selection for sow productivity at a litter ages of 42 days. Anim. Breed. Abstr. 45: 6: p.343.

JANCIC S., E. CRNOJRVIC, S. JAKSIC S. and M. BOLIC. 1980a. Evaluating the degree of heritability of some characters in pigs: Inheritance of reproductive characters in Large Whites. Anim. Breed. Abstr. 48: 6: p.363.

JANCIC, S., E. CRNOJEVIC, S. JAKSIC and M. BOLIC. 1980b. The heritability of some characters in pigs: inheritance of reproductive characters in Dutch Landraces. Anim. Breed. Abstr. 48: 10: p.716.

JANCIC, S., E. CRNOJEVIC, S. JAKSIC and R. ZEBEK. 1982a. Evaluating the degree of heritability of some characters in pigs: The inhertance of reproductive traits in Swedish Landrace. Anim. Breed. Abstr. 50: 11: p.749.

JANCIC, S., E. CRNOJEVIC, F. ZAGOZEN and S. JAKSIC. 1982b. The degree of heritability of some characters in pigs: Inheritance of some reproductive characters in purebred and crossbred pigs. Anim. Breed. Abstr. 50: 12: p.871.

JEON, J.T. and K.C. HONG. 1989. Estimation of genetic parameters and factors affecting the selection of foundation stock in line breeding pigs. J. Anim. Sci. 57: 12: 1015.

JOHANSSON, K. 1983. Is breeding for improved fertility unrewarding work? Anim. Breed. Abstr. 51: 7: p.549.

JOHANSSON, K. and B.W. KENNEDY. 1983. Estimation of genetic parameters of fertility traits in pigs. Anim. Breed. Abstr. 51: 5: p.360.

JOHANSSON, K. and B.W. KENNEDY. 1986. Estimation of genetic parameters for reproductive traits in pigs. Anim. Breed. Abstr. 54: 6: p.496

KARAM, H.A., A.B. CHAPMAN and A.L. POPE. 1953. Selecting lambs under farm conditions. J. Anim. Sci. 12: 148.

KEMPTHRORNE, O. and O.B. TANDON. 1953. The estimation of heritability by regression of offspring on parent. Biometrics. 9: 90.

KENNEDY, B.W., K. JOHANSSON and G.F.S. HUDSON. 1985. Heritabilities and genetic correlations for backfat and age at 90 kg in performance tested pigs. J. Anim. Sci. 61: 1:78-82.

KIM J.B., H.W. CHUNG and Y.I. PARK. 1989. Heritabilites and gentic correlations between litter size and litter weight in swine. Anim. Breed. Abstr.P 57: 6: p.533.

KRYATOV, O. V. 1972. Variability and heretability of economic traits in Ukrainian Spotted Steppe pigs. Anim. Breed. Abstr. 40: 3: p.541.

LAMBIO, A.L., V.G. ARGAÑOSA, and A.G. AQUINO. 1986. Genetic parameters of certain pre-breeding traits in swine. Phil. J. Anim. Sci. 12: 1 & 2: 26-34.

LAMBIO, A.L., V.G. ARGAÑOSA and J.N. VISPO. 1990a. Genetic parameter estimates in Yorkshire and Landrace breeds of swine. In: Terminal report on Genetic analysis of a commercial purebred swine population. PCARRD No. 89-915-21. p.1.

LAMBIO, A.L., V.G. ARGAÑOSA and J.N. VISPO. 1990b. Development of a selection index for commercial swine population in the Philippines. In: Terminal report on Genetic analysis of a cmoomercial purebred swine population. PCARRD No. 89-915-21. p.27.

LASLEY, J.F. 1987. Genetics of Livestock Improvement. Prentice-Hall. pp.477.

LOUCA, A. and O.W. ROBINSON. 1967. Heritability and genetic correlations in swine. J.Anim. Sci. 24: 850.

MAHMUD, A.B. 1970. Phenotypic and genetic parameters of pigling traits traits from birth to weaning. Anim. Breed. Abstr. 38: 1: p.120.

MALYSHEV, B.T. and E.N. SUSLINA 1988. Selection of pigs for litter size. Anim. Breed. Abstr. 56: 3: p.204.

McCARTER, M.N.JR., J.W. MABRY, J.K. BERTRAND and L.L. BENYSHEK. 1987. Components of variance and covariance for reproductive traits in swine estimated from Yorkshire field data. J. Anim. Sci. 64: 5: p.1285-1291.

McPHEE, C.P., P.J. BRENNAN and F. CUNCALFE. 1979. Genetic and phenotypic parameters of Australian Large White and Landrace boars performance tested when offered feed ad libitum. Anim. Prod. 28: 79.

MELTON, B.E., E.O. HEADY and R.L. WILLHAM. 1979. Estimation of economic values for selection indices. Anim. Prod. 28: 279-286.

MILAGRES, J.C., L.M. FEDALTO, M.DE.A.E. SILVA and R.F. EUCLEDES. 1983. Sources of variation in litter size and weight at birth and 21 days of age in Duroc, Landrace and Large White pigs. 5. Genetic parameters. Anim. Breed. Abstr. 51: 7: p.550.

MINKEMA, D., M. BEKEDAM, D. KROESKE and TH. STEGENGA. 1964. A selection experiment with pigs: Comparison of the effectiveness of individual selection and sib selection. Neth. J. Agric. Sci. 12: 4: 318-329.

MINUTIN, M.A. and Yu.K. SVECHIN. 1981. Variation, heritability and relationships of reproductive traits in Large White pigs. Anim. Breed. Abstr. 49: 2: p.89.

MITCHELL, G., C. SMITH, M. MAKOWER and P.J.W,N. BIRD. 1982. An economic appraisal of pig improvement in Great Britain. 1. Genetic and production aspects. Anim. Prod. 35 ; 215-224.

MORRIS, C.A., J.L. ADAM and D.L. JOHNSON. 1978. Breeding objectives and selection indices for Newzealand pig improvement. V.J. Jour. Expt. Agri. 6: 259-266.

MOSKVIN N. 1989. Variability of litter size. Anim. Breed. Abstr. 57: 12: p.106.

NAPOLES, L.P. 1985. Performance of the Pietrain breed of swine and its crosses. Unpublised M.S. Thesis, UPLB. p.89.

NIKOLIC, D., M. MILOJIC, B. SIMOVIC and L. LAZAREVIC. 1970. Heritability of fertility in Dutch Landraces bred in Yugoslavia. Anim. Breed. Abstr. 38: 4: p.639.

OMTVEDT, I.T., R.K. JOHNSON, L.E. WALTERS, T.W. WILLIAMS and S.D. WELTY. 1973. Swine cross-breeding results. 2-breed crosses Vs. purebreds. Anim. Breed. Abstr. 41: 11: 550.

OMTVEDT, I.T., J.A. WHATLEY, Jr. and R.L. WILLHAM. 1966. Some production factors associated with weaning records in swine. J. Anim. Sci. 35: 372.

PARK, D.S., S.B. CHUNG and H.Y. PARK. 1987. Estimates of the h^2s of economic traits in pigs. Anim. Breed. Abstr. 55: 10: p.784

PARK, Y.I., H.W. CHUNG and K.S. SEO. 1990. Estimation of genetic parameters for growth rate and backfat thickness in swine. Proceedings: The 5th AAAP Anim. Sci. Congress. May 27-June 1, 1990, Taiwan, R.O.C., Vol. 3: 258.

PARK, Y.I. and J.B. KIM. 1987. Heritabilities of litter size and litter weight at birth in swine. Anim. Breed. Abstr. 55: 1: p.48.

PEÑALBA, F.F. 1986a. Selection for increased litter size in swine. Phil. Jour. Vet. and Anim. Sci: 12: 1 & 2 p.14-25.

PEÑALBA, F.F. 1986b. Smallholder swine production. Anim. Prod. Tech. 2: 2: p.20.

PEÑALBA, F.F. 1989. Swine performance testing program. Anim. Husbandry and Agric. J. 23: 5: 20.

PHAM, N.H. 1972. Evaluation of response to selection of sow productivity and construction of a selection index. Unpublished M.S. Thesis. Univ. of the Phil. Los Banos.

POLTRASKY, J. 1978. Fattening performance and the carcass of improved types of Landrace in Slovakia. Anim. Breed. Abstr. 46: 5: 263.

POLYANICHKO, YA, I. 1973. Variability and heritability of some economic traits in purebred pigs. Anim. Breed. Abstr. 41: 4: p.196.

POPESCU-VIFOR, S. 1975. Genetic and environmental parameters of reproductive performence in swine. Anim. Breed. Abstr. 43: 4: p.140.

POPESCU-VIFOR, S. 1977. Genetic parameters of body weight in piglets up to 8 wk of age. Anim. Breed. Abstr. 45: 12: p.681.

PUYAOAN, R.B. 1971. Estimates of genetic, environmental and Phenotypic parameters of traits related to sow productivity. Unpublished Ph.D. thesis, University of the Philippines.

REVELLE, T.J. and O.W. ROBISON. 1973. An explanation for the low heritability of litter size in swine. J. Anim. Sci. 37: 3: p.668-675.

REUTZEL, F.L. and L.J. SUMPTION. 1968. Genetic and phenotypic relationships involving age at puberty and growth rate of gilts. J. Anim. Sci. 27: 27.

RHEE, R.Y., S.B. CHUNG and H.Y. PARK. 1987. Estimates of h^2s and genetic correlations of litter size and body weight in pigs. Anim. Breed. Abstr. 55: 10: p.784.

RICO, C. and J. GOMEZ. 1983. Interrelationships betweem reproductive performance traits in swine. Anim. Breed. Abstr. 51: 8: p.627.

ROBERTSON, A. 1959. The sampling variance of the genetic correlation coefficient. Biometrics. 15: 469-485.

ROBISON, O.W. and J.M. BERRUECOS. 1973. Feed efficiency in swine. II. Prediction of efficiency and genetic correlations with carcass traits. J. Anim. Sci. 37: 650.

ROBISON, O.W., A.B. CHAPMAN and H.L. SELF. 1960. swine selection indexes including live animal measurements as indicators of carcass merit. J. Sci. 19: 1024-1030.

ROTHSCHILD, M.F., J.P. CARLSON and L.L. CHRISTIOAN. 1981. Comparison of selection index economic weights and prices paid for performance tested boars. J. Anim. Sci. 53: 3: 575-579.

ROY, G.L., W.J. BOYLAN and M.E. SEALE. 1968. Estimates of genetic correlations among certain carcass and

performance traits in swine. Can. J. Anim. Sci. 48: 1.

SALAYOG, F.A. 1977. The economics of production and carcases characteristics of hogs feed two energy levels and raised to five different slight weights. Unpublished M.S. Thesis UPLB, p.83.

SAS INSTITUTE, 1985. Statistical Analysis System. user's guide: Statistics, Verson 5. Edition.

SCHLINDWEIN, A.P. and F.A.M. DUARTE. 1981. Genetic study of pre weaning performance in Duroc swine. Anim. Breed. Abstr. 49: 7: p.473.

SCHLINDWEIN, A.P., F.A.M., DUARTE, A. SPERS and L.A.F. BEZERRA. 1982. Correlations between pre weaning traits in Duroc swine. Anim. Breed. Abstr. 50: 11: p.750.

SCHLINOWEIN, A.P., J.R. TORRES and G.G. CARNE. 1980. Heritability estimates of litter size and piglet birth weight in Duroc pigs. Anim. Breed. Abstr. 48: 4: p.214.

SHRESTHA, N.P.and B.B. GURUNG. 1989. Comparative study of life long production performance of three genotypes of pigs. Nep. J. Anim. Sci. 5: 5: p.41.

SHRESTHA, N.P., D.R. PRADHAN and B.B. GURUNG. 1988. Study of pig production system adopted by Pig Breeder Farmers around Pokhara Valley. Lampatan Livestock Research Station Animal Report 2044/45.

SHI, Q.S., X.C. LIU and Y.Y. LI. 1987. Studies on the heritability of quantitative characters in Ningxing pigs. 1. Reproductive characters. Anim. Breed. Abstr. 55: 9: p.702.

SIAGIAN, P.H. 1984. Comparative performance of Landrace, Duroc and Yorkshire breeds of swine. Unpublished Ph.D. Thesis. UPLB, College, Laguna, Philippines. 172 pp.

SILVER, R. and J. PAVLIK. 1982. The phenotypic and genetic analysis of fertility in sows. Anim. Breed. Abstr. 50: 11: p.751.

SILVINSKAYA, E. 1974. Selection for litter size. Anim. Breed. Abstr. 42: 12: p.618.

SLANGER,W.D. and B.O. OGUNLOLA. 1983. A simple method of obtaining selecton index weights. J. Anim. Sci. 56: 5: 1029-1032.

SMITH, C., G.E. DICKERSON, M.W. TESS and G.L. BENNETT. 1983. Expected relative responses to selection for alternative measures of life cycle economic efficiency of pork production. J. Anim. Sci. 56: 1306-1314.

SMITH, C., J.W.B. KING and N. GILBERT. 1962. Genetic parameters of British Large White bacon pigs. Anim. Prod. 4: Part 1:128-143.

SMITH, C. and G.J.S. ROSS. 1965. Genetic parameters of British Land race bacon pigs. Anim. Prod. 7: Part 3: 291-301.

SMITH, H.F. 1936. A discriminant function for plant selection. Ann. Eugen. 7: 240.

STANKOVIC, M. 1977. The possibility of improving the reproductive perfomance of filial generations of sows using selected dam and sires. Anim. Breed. Abstr. 45: 2: p.116.

STOCKHAUSEN, C.W.F. and W.J. BOYLAN. 1966. Heritability and genetic correlation estimates in a new breed of swine. Canad. J. Anim. Sci. 46: 211.

STRANG, G.S. 1970. Litter productivity in Large White pigs. 1. The relative importance of some sources of variation. Anim. Prod. 12: 225-233.

STRANG, G.S. and J.W.B. KING. 1970. Litter productivity in Large White pigs. 2. Heritability and repeatability estimates. Anim. Prod. 12: 235-243.

STRANG, G.S. and C. SMITH. 1979. A note on the heritability of litter traits in pigs. Anim. Prod. 28: 2: 403-406.

SWIGER, L.A., G.A. ISLER and W.R. HARVEY. 1978. Postweaning genetic parameters and indices for swine. J. Anim. Sci. 48:5: 1096-1100.

THOMECZEK, F.J., M.R. ELLERSIEK, R.K. LEAVITT and J.F. LASLEY. 1978. Trends in economic traits of production tested boars in the Missouri evaluation station. Anim. Breed. Abstr. 47: 2: 87.

TOELLE, V.D. and O.W. ROBISON. 1986. Estimates of genetic relationship between tests measurements and female reproductive traits in swine. Anim. Breed. Abstr. 54: 1: p.46.

TRIEBLER, G. 1989. Parameters of age at puberty of gilts in large herds. Anim. Breed. Abstr. 57: 7: p.629.

VALAREZO, J.M. and B. QUIJANDRIA. 1979. Genetic parameters for production characters in duroc piglets. Anim. Breed. Abstr. 47: 10: 609.

VALJNEVA, V.I. 1969. The effectiveness of crossing Large White dams with Landrace boars. Anim. Breed. Abstr. 37: 3: 470.

VAN DIEPEN, T.A. and B.W. KENNEDY. 1989. Genetic correlations between test station and on-farm performance for growth rate and backfat in pigs. J. Anim. Sci. 67: 1425- 1431.

VANGELOV, K. 1970. Heritability of some characters in Large White pigs. Anim. Breed. Abstr. 38: 3: p.464.

VASILEVA, I., ANDREEV A.P. and MISHEV, P. 1978. Phenotypic and genetic parameters of some traits in Bulgarian White pigs. Anim. Breed. Abstr. 46: 1: p.46.

VENEV, I. 1981. The possibility of selecting pigs for litter size. Anim. Breed. Abstr. 49: 7: p.473.

VIDOVIC, V. 1979. Genetic parameters of reproductive characters of purebred and crossbred pigs. Anim. Breed. Abstr. 47: 3: p.143.

WALKER, I.J., R.G. BEILHARZ and A.C. DUNKIN. 1973. A genetic study of reproductive perfomance of sows in a large commercial pig herd. Anim. Breed. Abstr. 41: 11: p.549.

WARWICK, E.J. and J. E. LEGATES. 1980. Breeding and Improvement of farm animals. McGraw-Hill. pp.625.

WILSON, E.R. and R.K. JOHNSON. 1981. Comparision of mating systems with Duroc, Hampshire and Yorkshire breeds of swine for efficiency of swine production. J. Anim. Sci. 52: 1: 26- 36.

WILSON, E.R., R.K. JOHNSON, L.E. WALTERS, S.D. WELTY and J. SHOOLY. 1979. Growth and carcass traits for

pigs of four swine breeds and their crosses. Anim. Breed. Abstr. 47: 5: 250.

WU, J.S. and W.C. ZHANG. 1983. Genetic analysis of some Chinese breeds as a resource for world hog improvement. Anim. Breed. Abstr. 51: 5: p.361.

YOUNG, L.D., I.T. OMTVEDT and R.K. JOHNSON. 1974. Relationships of various measures of performance with ovulation rate and number of embryos 30 days after breeding in gilts. J. Anim. Sci. 39: 937.

YOUNG, L.D., R.A. PUMFREY, P.J. CUNNINGHAM and D.R. ZIMMERMAN. 1978. Heritabilities and genetic and phenotypic correlations for prebreeding traits and principal components. J. Anim. Sci. 46: 4: 937.

ZHANG, W.C. 1983. A study of phenotypic and genetic parameters of reproductive traits in Tai Hu pigs and several recommended selection indices. Anim. Breed. Abstr. 51: 6: p.465.

ZOENELLER, K.O., J.F. LASLEY, L.F. TRIBBLE and B.N. DAY. 1963. Selection for thinner backfat in swine. Mo. Exp. Sta. Res. Bull. 831.

ZSCHORLICH, B. and E. RITTER 1989. Improvement of litter quality by means of breeding. Anim. Breed. Abstr. 57: 11: p.946.

APPENDICES

Appendix Table 1. Number of obsevations on litter performance traits by different categories of sire, dams, litters and their breed groups.

CATEGORIES	TRAITS LSB	LBW	LSW	PWT	LWW	AWW
Sires:						
L	4	4	4	4	4	4
Y	1	1	1	1	1	1
LxY	2	2	2	2	2	2
Total	7	7	7	7	7	7
Dams:						
L	28	28	27	27	16	16
Y	14	14	13	13	8	8
LxY	17	17	16	16	11	11
Total	59	59	56	56	35	35
Litters:						
L	54	54	51	51	38	38
Y	8	8	8	8	5	5
LxY	85	85	81	81	42	42
Total	147	147	140	140	85	85
Total piglets:	1387	1387	1307	1307	784	784

Note:
L = Landrace; Y = Yorkshire; LxY = Landrace x Yorkshire.

Appendix Table 2.1. Least square Analysis of Variance for LSB.

VARIANCE SOURCE	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARES	VARIANCE COMPONENTS
Among Sires	6	59.419	9.903ns	0.155
Within Sires: Among Dams	52	348.251	6.697ns	0.547
Within Dams: Among Litters	88	470.467	5.346	5.346
Total	146	878.136	6.015	6.048

ns = non-significant.
Coefficients:- k1= 2.47, k2= 2.64, k3= 20.15.
R^2= 0.46, C.V.= 24.51%

Appendix Table 2.2. Least Square Analysis of Variance for LBW.

VARIANCE SOURCE	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARES	VARIANCE COMPONENTS
Among Sires	6	122.244	20.374*	0.355
Within Sires: Among Dams	52	667.513	12.837**	2.239
Within Dams: Among Litters	88	643.006	7.307	7.307
Total	146	1432.764	9.814	9.901

* = Significant at P<0.05, ** = significant at P<0.01.
Coefficients:- k1= 2.47, k2= 2.64, k3= 20.15.
R^2= 0.53, C.V.= 25.49%.

Appendix Table 2.3. Least Square Analysis of Variance for LSW.

VARIANCE SOURCE	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARES	VARIANCE COMPONENTS
Among Sires	6	77.226	12.871*	0.327
Within Sires: Among Dams	49	318.200	6.494ns	0.783
Within Dams: Among Litters	84	382.367	4.552	4.552
Total	139	777.793	5.596	5.663

* = significant at P<0.05; ns = non-significant.
Coefficients:- k1 = 2.48, k2 = 2.63, k3 = 19.09
R^2 = 0.51, C.V. = 30.89%

Appendix Table 2.4. Least Square Analysis of Variance for PWT.

VARIANCE SOURCE	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARES	VARIANCE COMPONENTS
Among Sires	6	5767	961.159*	25.741
Within Sires: Among Dams	49	22806	465.419ns	28.148
Within Dams: Among Litters	84	33234	395.638	395.638
Total	139	61806	444.648	449.528

* = significant at P<0.05; ns = non-significant.
Coefficients:- K1= 2.47, K2= 2.63, K3= 19.09.
R^2= 0.46, C.V.= 26.42%.

Appendix Table 2.5. Least Square Analysis of Variance for LWW.

VARIANCE SOURCE	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARES	VARIANCE COMPONENTS
Among Sires	6	9216.799	1536.133**	113.842
Within Sires: Among Dams	28	6832.242	244.009ns	13.551
Within Dams: Among Litters	50	10560.458	211.209	211.209
Total	84	26609.499	316.780	338.602

** Significant at P<0.01; ns = non-significant.
Coefficients:- k1= 2.42, k2= 2.43, k3= 11.22.
R^2= 0.60, C.V.= 30.91%.

Appendix Table 2.6. Least Square Analysis of Variance for AWW.

VARIANCE SOURCE	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARES	VARIANCE COMPONENTS
Among Sires	6	48.473	8.079*	0.372
Within Sires: Among Dams	28	107.788	3.849ns	0.409
Within Dams: Among Litters	50	142.915	2.858	2.858
Total	84	299.176	3.562	3.640

* = Significant at P<0.05; ns = non-significant.
Coefficients:- k1= 2.42 k2= 2.42 k3= 11.22.
R^2= 0.52, C.V.= 25.51%.

Appendix Table 3.1. Analysis of covariance for LSB and LBW.

COVARIANCE SOURCE	DEGREES OF FREEDOM	SUM OF PRODUCTS	MEAN PRODUCTS	COVARIANCE COMPONENTS
Between Sires	6	70.849	11.808	0.293
Within sires:				
between Dams	52	300.567	5.78	0.719
Within Dams:				
between litters	88	352.25	4.003	4.003
Total	146	723.66	4.957	5.016

Coefficients:- k1 = 2.47; k2 = 2.64; k3 = 20.15.

Appendix Table 3.2. Analysis of covariance for LSB and LSW.

COVARIANCE SOURCE	DEGREES OF FREEDOM	SUM OF PRODUCTS	MEAN PRODUCTS	COVARIANCE COMPONENTS
Between Sires	6	38.416	6.403	0.137
Within sires:				
between Dams	49	181.964	3.714	0.451
Within Dams:				
between litters	84	217.983	2.595	2.595
Total	139	438.364	3.154	3.183

Coefficients:- k1 = 2.47; k2 = 2.63; k3 = 19.09.

Appendix Table 3.3. Analysis of covariance for LSB and PWT.

COVARIANCE SOURCE	DEGREES OF FREEDOM	SUM OF PRODUCTS	MEAN PRODUCTS	COVARIANCE COMPONENTS
Between Sires	6	-13.977	-2.329	0.27
Within sires:				
between Dams	49	-389.577	-7.951	3.085
Within Dams:				
between litters	84	-1310.278	-15.599	-15.599
Total	139	-1713.832	3.711	-12.244

Coefficients:- k1 = 2.47; k2 = 2.63; k3 = 19.09.

Appendix Table 3.4. Analysis of covariance for LSB and LWW.

COVARIANCE SOURCE	DEGREES OF FREEDOM	SUM OF PRODUCTS	MEAN PRODUCTS	COVARIANCE COMPONENTS
Between Sires	6	637.132	106.189	8.323
Within sires: between Dams	28	328.137	11.719	1.63
Within Dams: between litters	50	387.706	7.754	7.754
Total	84	1352.974	16.107	17.715

Coefficients:- k1 = 2.42; k2 = 2.43; k3 = 11.35.

Appendix Table 3.5. Analysis of covariance for LSB and AWW.

COVARIANCE SOURCE	DEGREES OF FREEDOM	SUM OF PRODUCTS	MEAN PRODUCTS	COVARIANCE COMPONENTS
Between Sires	6	41.035	6.839	0.735
Within sires: between Dams	28	-42.133	-1.505	0.206
Within Dams: between litters	50	-100.182	-2.004	-2.004
Total	84	-101.28	-1.206	-1.063

Coefficients:- k1 = 2.42; k2 = 2.43; k3 = 11.35.

Appendix Table 3.6. Analysis of covariance for LBW and LSW.

COVARIANCE SOURCE	DEGREES OF FREEDOM	SUM OF PRODUCTS	MEAN PRODUCTS	COVARIANCE COMPONENTS
Between Sires	6	77.121	12.853	0.445
Within sires: between Dams	49	209.333	4.272	0.622
Within Dams: between litters	84	229.328	2.730	2.730
Total	139	515.781	3.711	3.797

Coefficients:- k1 = 2.47; k2 = 2.63; k3 = 19.09.

Appendix Table 3.7. Analysis of covariance for LBW and PWT.

COVARIANCE SOURCE	DEGREES OF FREEDOM	SUM OF PRODUCTS	MEAN PRODUCTS	COVARIANCE COMPONENTS
Between Sires	6	275.466	45.911	2.308
Within sires:				
between Dams	49	79.653	1.626	1.484
Within Dams:				
between litters	84	-172.541	-2.054	-2.054
Total	139	182.578	1.314	1.738

Coefficients:- k1 = 2.47; k2 = 2.63; k3 = 19.09.

Appendix Table 3.8. Analysis of covariance for LBW and LWW.

COVARIANCE SOURCE	DEGREES OF FREEDOM	SUM OF PRODUCTS	MEAN PRODUCTS	COVARIANCE COMPONENTS
Between Sires	6	882.029	147.005	10.255
Within sires:				
between Dams	28	855.725	30.562	5.557
Within Dams:				
between litters	50	855.563	17.111	17.111
Total	84	2593.318	30.873	32.924

Coefficients:- k1 = 2.42; k2 = 2.43; k3 = 11.35.

Appendix Table 3.9. Analysis of covariance for LBW and AWW.

COVARIANCE SOURCE	DEGREES OF FREEDOM	SUM OF PRODUCTS	MEAN PRODUCTS	COVARIANCE COMPONENTS
Between Sires	6	51.673	8.612	0.842
Within sires:				
between Dams	28	-26.488	-0.946	-0.167
Within Dams:				
between litters	50	-27.069	-0.541	-0.541
Total	84	-1.884	-0.022	0.134

Coefficients:- k1 = 2.42; k2 = 2.43; k3 = 11.35.

Appendix Table 3.10. Analysis of covariance for LSW and PWT.

COVARIANCE SOURCE	DEGREES OF FREEDOM	SUM OF PRODUCTS	MEAN PRODUCTS	COVARIANCE COMPONENTS
Between Sires	6	539.847	89.975	2.68
Within sires:				
between Dams	49	1864.958	38.06	4.923
Within Dams:				
between litters	84	2171.848	25.855	25.855
Total	139	4576.654	32.926	33.458

Coefficients:- k1 = 2.47; k2 = 2.63; k3 = 19.09.

Appendix Table 3.11. Analysis of covariance for LSW and LWW.

COVARIANCE SOURCE	DEGREES OF FREEDOM	SUM OF PRODUCTS	MEAN PRODUCTS	COVARIANCE COMPONENTS
Between Sires	6	820.505	136.751	10.068
Within sires:				
between Dams	28	629.155	22.47	2.119
Within Dams:				
between litters	50	867.052	17.341	17.341
Total	84	2316.711	27.58	29.528

Coefficients:- k1 = 2.42; k2 = 2.43; k3 = 11.35.

Appendix Table 3.12. Analysis of covariance for LSW and AWW.

COVARIANCE SOURCE	DEGREES OF FREEDOM	SUM OF PRODUCTS	MEAN PRODUCTS	COVARIANCE COMPONENTS
Between Sires	6	43.497	7.241	0.83
Within sires:				
between Dams	28	-60.795	-2.171	-0.341
Within Dams:				
between litters	50	-67.338	-1.347	-1.347
Total	84	-84.686	-1.008	-0.858

Coefficients:- k1 = 2.42; k2 = 2.43; k3 = 11.35.

Appendix Table 3.13. Analysis of covariance for PWT and LWW.

COVARIANCE SOURCE	DEGREES OF FREEDOM	SUM OF PRODUCTS	MEAN PRODUCTS	COVARIANCE COMPONENTS
Between Sires	6	3452.555	575.426	38.126
Within sires:				
between Dams	28	3892.174	142.578	15.726
Within Dams:				
between litters	50	5225.761	104.515	104.515
Total	84	12670	150.839	158.367

Coefficients:- k1 = 2.42; k2 = 2.43; k3 = 11.35.

Appendix Table 3.14. Analysis of covariance for PWT and AWW.

COVARIANCE SOURCE	DEGREES OF FREEDOM	SUM OF PRODUCTS	MEAN PRODUCTS	COVARIANCE COMPONENTS
Between Sires	6	128.359	21.393	2.517
Within sires:				
between Dams	28	-199.803	-7.136	-3.726
Within Dams:				
between litters	50	94.15	1.883	1.883
Total	84	22.705	0.27	0.674

Coefficients:- k1 = 2.42; k2 = 2.43; k3 = 11.35.

Appendix Table 3.15. Analysis of covariance for LWW and AWW.

COVARIANCE SOURCE	DEGREES OF FREEDOM	SUM OF PRODUCTS	MEAN PRODUCTS	COVARIANCE COMPONENTS
Between Sires	6	592.983	98.83	7.546
Within sires:				
between Dams	28	369.388	13.192	0.369
Within Dams:				
between litters	50	614.966	12.299	12.299
Total	84	1577.337	18.778	20.214

Coefficients:- k1 = 2.42; k2 = 2.43; k3 = 11.35.

Appendix Table 4. Stepwise Regression Analysis of PWT and AWW of the Litter Production function on Litter Output (LSW) using Backward Elimination Procedure:

Step- 0 All Variables Entered $R^2 = 0.40$, C(p) = 6.00

VARIANCE SOURCE	DF	SUM OF SQUARES	MEAN SQUARES	F value
Regression	5	189.078	37.816	10.57**
Error	79	282.734	3.579	
Total	84	471.812		

Variable	Parameter Estimate	Standard Error	Sum of squares	F value
Intercept	0.443	4.9885	0.02822248	0.01
PWT	0.154	0.0832	12.17256381	3.40
AWW	-0.289	0.8427	0.42123803	0.12
PWT^2	-0.00013	0.0005	0.28506614	0.08
AWW^2	0.05039	0.0394	5.85120367	1.63
PWTxAWW	-0.00952	0.0068	7.12416355	1.99

Step 1 Variable PWT^2 Removed $R^2 = 0.40$ C(p) = 4.08

VARIANCE SOURCE	DF	SUM OF SQUARES	MEAN SQUARES	F VALUE
Regression	4	188.793	47.198	13.34**
Error	80	283.019	3.538	
Total	84	471.812		

Variable	Parameter Estimate	Standard Error	Sum of Squares	F value
Intercept	1.148	4.291	0.253	0.07
PWT	0.134	0.045	31.950	9.03**
AWW^2	-0.303	0.836	0.465	0.13
AWW^2	0.051	0.039	6.063	1.71
PWTxAWW	-0.010	0.007	7.041	1.99

DF = Degrees of freedom.

Appendix Table 4. continued.

Step-2 Variable AWW Removed $R^2 = 0.40$ C(p) = 2.21

VARIANCE SOURCE	DF	SUM OF SQUARES	MEAN SQUARES	F VALUE
Regression	3	188.328	62.776	17.94**
Error	81	283.484	3.50	
Total	84	471.812		

Variable	Parameter Estimate	Standard Error	Sum of Squares	F value
Intercept	-0.315	1.453	0.164	0.05
PWT	0.145	0.033	69.175	19.77**
AWW^2	0.040	0.025	8.989	2.57
PWTxAWW	-0.011	0.005	19.511	5.58*

Step-3 Variable AWW Removed $R^2 = 0.38$ C(p) = 2.72 (Final Model).

VARIANCE SOURCE	DF	SUM OF SQUARES	MEAN SQUARES	F VALUE
Regression	2	179.339	89.669	25.14**
Error	82	292.473	3.567	
Total	84	471.812		

Variable	Parameter Estimate	Standard Error	Sum of Squares	F value
Intercept	1.502	0.918	9.559	2.68
PWT	0.098	0.014	169.025	47.39**
PWTxAWW	-0.004	0.001	29.941	8.39**

** = significant at (P<0.01); * = significant at (P<0.05).
C(p) = Mallow's criterion (SAS Institute, 1985).

Appendix Table 5. Stepwise Regression Analysis of LSB and LBW of Litter Production function on Litter output (LSW) using Backward Elimination Procedure:

Step-0 All Variables Entered $R^2 = 0.45$ C(p) = 6.00

VARIANCE SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
Regression	5	215.349	43.070	13.27**
Error	79	256.463	3.246	
Total	84	471.812		

Variable	Parameter Estimate	Standard Error	Sum of Squares	F value
Intercept	-0.946	1.949	0.765	0.24
LSB	0.664	0.545	4.829	1.49
LBW	0.470	0.372	5.181	1.60
LSB^2	-0.011	0.029	0.439	0.14
LBW^2	-0.009	0.012	1.988	0.61
LSBxLBW	-0.007	0.028	0.204	0.06

Step-1 Variable LSBxLBW Removed $R^2 = 0.46$ C(p) = 4.06

VARIANCE SOURCE	DF	SUM OF SQUARES	MEAN SQUARES	F VALUE
Regression	4	215.145	53.786	16.76**
Error	80	256.667	3.208	
Total	84	471.812		

Variable	Parameter Estimate	Standard Error	Sum of Squares	F value
Intercept	-0.727	1.733	0.565	0.18
LSB	0.66446115	0.542	4.826	1.50
LBW	0.41973344	0.312	5.821	1.81
LSB^2	-0.01357667	0.026	0.878	0.27
LBW^2	-0.01063002	0.011	3.019	0.94

Appendix Table 5. continued.

Step-2 Variable LSB² Removed $R^2 = 0.45$ C(p) = 2.33

VARIANCE SOURCE	DF	SUM OF SQUARES	MEAN SQUARES	F VALUE
Regression	3	214.267	71.42236950	22.46**
Error	81	257.545	3.17956366	
Total	84	471.812		

Variable	Parameter Estimate	Standard Error	Sum of Squares	F value
Intercept	-0.091	1.229	0.018	0.01
LSB	0.387	0.109	40.189	12.64**
LBW	0.525	0.238	15.484	4.87*
LBW²	-0.014	0.009	8.180	2.57

Step-3 Variable LBW² Removed $R^2 = 0.44$ C(p) = 2.85 (Final Model).

VARIANCE SOURCE	DF	SUM OF SQUARES	MEAN SQUARES	F VALUE
Regression	2	206.087	103.043	31.80**
Error	82	265.725	3.241	
Total	84	471.812		

Variable	Parameter Estimate	Standard Error	Sum of Squares	F value
Intercept	1.478	0.750	12.570	3.88*
LSB	0.442	0.104	58.075	17.92**
LBW	0.163	0.077	14.622	4.51*

** = significant at (P<0.01); * = significant at (P<0.05).
C(p) = Mallow's criterion (SAS Institute, 1985).

Appendix Table 6. Assumptions of Technical coefficients for computation of cost of production of a on-farm tested Nieuw Dalland market hog.

CRITERIA/ ITEMS	RATE/ PRICE/ VALUE	SOURCE OF INFORMATION
A. Initial stock cost:		
1. for first 10 kg body weight	P 750.00	ITCPH, Lipa.
2. for second 10 kg body weight	P 40.00/kg	ITCPH, Lipa.
3. for additional body weight beyond 20 kg	P 35.00/kg	ITCPH, Lipa.
B. Fixed costs:		
1. Land cost:		
a. Land area of 25000 sqm for housing 84 pigs	P 100.00/sq m	Bureau of internal Revenue, Lipa.
b. Land interest dividend	18% per annum	ITCPH, Lipa.
2. Housing cost:		
a. Replecement value of commercial unit for 84 pigs	P 453051.70	ITPCH, Lipa
b. Salvage value after 20 years	P 90610.30	ITPCH, Lipa
c. Total depreciation value	P 362441.40	ITCPH, Lipa
d. Economic life time	20 years	ITPCH, Lipa
e. Depreciation rate	0.05% per annum	ITPCH, Lipa
f. Average value of housing investment	P 271831.00	ITPCH, Lipa
g. Interest rate on housing investment	18% per annum	ITPCH, Lipa
h. Repair & maintenance cost of housing (on the basis of average value of investment)	5% per annum	ITPCH, Lipa

Appendix Table 6. continued.

CRITERIA/ ITEMS	RATE/ PRICE/ VALUE	SOURCE OF INFORMATION
3. Equipment cost:		
a. Depreciation on major equipment valued at P 45,000.00	10% per annum	ITPCH, Lipa
b. Interest on investment on major equipment	18% per annum	ITPCH, Lipa
c. Depreciation of minor equipment valued at P 5000.00	20% per annum	ITPCH, Lipa
d. Interest on minor equipment investment	18% per annum	ITPCH, Lipa
C. Variable costs:		
1. Labor cost of one laborer for 80 pigs	P 70 per day	ITPCH, Lipa
2. Veterinary drugs/ disinfectants	P 0.35 per pig/day	ITPCH, Lipa
3. Water consumed	0.021 cu m per pig/day	This study
a. Average water charge	P 3.00 /cu m	Water District
4. Electricity consumed	0.027 KWatt per pig/day	This study
a. Average wattage price	P 2.5/KWatt	BATELEC Co.
5. Interest on working capital	18% per annum	ITPCH, Lipa
6. Average price of grower-finisher feed	P 6.40 per kg	DATACON, 1990
D. Sales:		
1. Average sale price of marketable live hog	P 34.43 per kg	DATACON, 1990

Appendix Table 7. Regression Analysis of Production function on Final weights (FWT) of Marketable Nieuw Dalland hogs (Before removing non-significant variables).

VARIANCE SOURCE	DF	SUM OF SQUARES	MEAN SQUARES	F VALUE
Model	14	2604.462	186.033	84.71**
ADG	1	611.214	611.214	278.32**
FCR	1	153.677	153.677	69.98**
BFT	1	711.610	711.610	324.03**
COP	1	1103.518	1103.518	502.49**
ADG²	1	2.794	2.794	1.27ns
FCR²	1	2.632	2.632	1.20ns
BFT²	1	1.139	1.139	0.52ns
COP²	1	0.020	0.020	0.01ns
ADGxFCR	1	8.160	8.160	3.72ns
ADGxBFT	1	1.823	1.823	0.83ns
ADGxCOP	1	3.963	3.963	1.80ns
FCRxBFT	1	3.861	3.861	1.76ns
FCRxCOP	1	0.001	0.001	0.00ns
BFTxCOP	1	0.050	0.050	0.02ns
Error	26	57.098	2.196	
Total	40	2661.561		

Parameter	Estimate	S.E. of Estimate
INTERCEPT	-580.8288836	285.11976040
ADG	805.6174506	454.83239867
FCR	243.4876885	133.73096848
BFT	88.0362499	86.41180650
COP	-0.0311114	0.07777692
ADG²	-259.2172546	195.94726662
FCR²	-21.5431001	13.39351434
BFT²	-4.1101856	5.35436148
COP²	0.0000092	0.00001106
ADGxFCR	-165.6217963	104.06445617
ADGxBFT	-36.5158189	58.92948716
ADGxCOP	0.0252581	0.05173929
FCRxBFT	-15.2940039	14.89315414
FCRxCOP	-0.0011353	0.01485372
BFTxCOP	-0.0019370	0.01288614

** = significant at (P<0.01);
ns = nonsignificant at (P<0.05).
R^2 = 0.98; C.V. = 1.78%.

Appendix Table 8. Regression Analysis of Production function on Final weights (FWT) of Marketable Nieuw Dalland hogs (Final Model).

VARIANCE SOURCE	DF	SUM OF SQUARES	MEAN SQUARES	F VALUE
Model	4	2580.019357	645.004839	284.76**
ADG	1	611.214283	611.214283	269.85**
FCR	1	153.677395	153.677395	67.85**
BFT	1	711.609788	711.609788	314.17**
COP	1	1103.517890	1103.517890	487.19**
Error	36	81.54161	2.265045	
Total	40	2661.560976		

Parameter	Estimate	S.E. of Estimate
INTERCEPT	25.09736070	9.20930413
ADG	10.44743607	6.35677429
FCR	-15.20051337	1.69503511
BFT	1.67452818	1.38058117
COP	0.03208982	0.00145384

** = Significant at (P<0.01);
R^2 = 0.97; C.V. = 1.81%.

NARC
LIBRARY

DATE DUE

NARC2000864

NARC Library
Call No. D 636.4 RAS Acc No. 864
Author Rakali, D.P
Title Genetic phenotypic

D
636.4
RAS
1991

864

NARC LIBRARY
KHUMALTAR